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MECHANICS

THE BOUNDARY DYNAMIC PROBLEM OF THE THEORY OF ELASTICITY FOR A CIRCLE WITH A GIVEN TENSION

By J. A. MINDLIN

(Communicated by I. M. Vinogradow, Member of the Academy, 7. V. 1937)

We give, in this paper, a solution of the problem of oscillation of a circle of radius R under initial zero-conditions and given components $\widehat{rr}$, $\widehat{r\theta}$ of the tension vectors acting on the area normal to r. Projections of the vectors of displacement in the polar coordinates are:

$$u_r = \frac{\partial \varphi}{\partial r} + \frac{1}{r}\frac{\partial \psi}{\partial \theta}; \quad u_\theta = \frac{1}{r}\frac{\partial \varphi}{\partial \theta} - \frac{\partial \psi}{\partial r}, \tag{1}$$

where functions φ and ψ satisfy the equations:

$$\frac{1}{a^2}\frac{\partial^2 \varphi}{\partial t^2} = \Delta\varphi; \quad \frac{1}{b^2}\frac{\partial^2 \psi}{\partial t^2} = \Delta\psi, \tag{2}$$

$$a = \sqrt{\frac{\lambda + 2\mu}{\rho}}; \quad b = \sqrt{\frac{\mu}{\rho}}, \tag{3}$$

by ρ we denote density of the medium, by λ and μ elastic constants of Lamé.

Components $\widehat{rr}$ and $\widehat{r\theta}$ of the vectors of tension are determined by the following formulae:

$$\rho^{-1}\widehat{rr} = a^2\frac{\partial^2 \varphi}{\partial r^2} + (a^2 - 2b^2)\left(\frac{1}{r^2}\frac{\partial^2 \varphi}{\partial \theta^2} + \frac{1}{r}\frac{\partial \varphi}{\partial r}\right) - 2b^2\left(\frac{1}{r^2}\frac{\partial \psi}{\partial \theta} - \frac{1}{r}\frac{\partial^2 \psi}{\partial r \partial \theta}\right); \tag{4}$$

$$\rho^{-1}\widehat{r\theta} = 2b^2\left(\frac{1}{r}\frac{\partial^2 \varphi}{\partial r \partial \theta} - \frac{1}{r^2}\frac{\partial \varphi}{\partial \theta}\right) + b^2\left(-\frac{\partial^2 \psi}{\partial r^2} + \frac{1}{r^2}\frac{\partial^2 \psi}{\partial \theta^2} + \frac{1}{r}\frac{\partial \psi}{\partial r}\right). \tag{5}$$

Let us assume that the boundary condition has the following form:

$$\widehat{rr}|_{r=R} = \rho\alpha_n(t)\, e^{in\theta}; \quad \widehat{r\theta}|_{r=R} = \rho\beta_n(t)\, e^{in\theta}, \tag{6}$$

where n is integer or zero.

To find the functions sought, φ_n and ψ_n, we use the principle of superposition (1).

We have

$$\left.\begin{aligned}\varphi_n &= \int_0^{2\pi} f_n(x\cos\lambda + y\sin\lambda + at)\, e^{in\lambda}\, d\lambda,\\ \psi_n &= \int_0^{2\pi} F_n(x\cos\lambda + y\sin\lambda + bt)\, e^{in\lambda}\, d\lambda.\end{aligned}\right\} \quad (a)$$

The functions φ_n and ψ_n in the polar coordinates have the form:

$$\varphi_n = \int_0^{\pi} A_n(r\cos\xi + at)\cos n\xi\, d\xi e^{in\theta}, \quad \psi_n = \int_0^{\pi} B_n(r\cos\xi + bt)\cos n\xi\, d\xi e^{in\theta}. \quad (b)$$

Satisfying the boundary conditions (6), after simple transformations we obtain a system of integral equations for the determination of the complex functions $A_n(\tau)$, $B_n(\tau)$:

$$\left.\begin{aligned}&\int_0^{\pi} A_n''(R\cos\xi + at)\,[(a^2 - b^2)\cos n\xi + b^2\cos(n+2)\xi]\, d\xi -\\ &- ib^2\int_0^{\pi} B_n''(R\cos\xi + bt)\cos(n+2)\xi d\xi = \alpha_n(t) + i\beta_n(t);\\ &\int_0^{\pi} A_n''(R\cos\xi + at)\,[(a^2 - b^2)\cos n\xi + b^2\cos(n-2)\xi]\, d\xi +\\ &+ ib^2\int_0^{\pi} B_n''(R\cos\xi bt)\cos(n-2)\xi\, d\xi = \alpha_n(t) - i\beta_n(t).\end{aligned}\right\} \quad (7)$$

As the initial and boundary conditions do not contradict each other, we have

$$\alpha_n(0) = 0,\ \alpha_n'(0) = 0;\quad \beta_n(0) = 0,\ \beta_n'(0) = 0.$$

Therefore the integral equations (7) for $t = 0$ are satisfied if we put the functions:

$$A_n''(\tau) = 0,\ B_n''(\tau) = 0. \qquad -R \leqslant \tau \leqslant R. \quad (8)$$

Let us replace in both parts of the equation (7) the variable t by a new variable x determined by the equation $x = R + at$. We introduce into the first terms of the left part of the equation (7) a new variable of integration $y = R\cos\xi + x - R$, and in the second terms we put $R\cos\xi + \frac{b}{a}x = \frac{b}{a}y + R$; then for t varying in the interval $0 \leqslant t \leqslant \frac{R}{a}$ (which corresponds to the variation of x in the interval $R \leqslant x \leqslant 2R$) accordingly to the conditions (8) we get:

$$\int_{\cdot}^{x} \frac{A_n''(y)\left[(a^2 - b^2)\, T_n\left(\frac{y+R-x}{R}\right) + b^2 T_{n-2}\left(\frac{y+R-x}{R}\right)\right] dy}{\sqrt{R^2 - (y+R-x)^2}} +$$

$$+\frac{ib^3}{a}\int_R^x \frac{B_n''\left[\frac{b}{a}y+R\left(1-\frac{b}{a}\right)\right]T_{n-2}\left[\frac{\frac{b}{a}(y-x)+R}{R}\right]dy}{\sqrt{R^2-\left[\frac{b}{a}(y-x)+R\right]^2}}=$$

$$=\alpha_n\left(\frac{x-R}{a}\right)-i\beta_n\left(\frac{x-R}{a}\right); \qquad (9)$$

$$\int_R^x \frac{A_n''(y)\left[(a^2-b^2)T_n\left(\frac{y+R-x}{R}\right)+b^2T_{n+2}\left(\frac{y+R-x}{R}\right)\right]dy}{\sqrt{R^2-(y+R-x)^2}}-$$

$$-\frac{ib^3}{a}\int_R^x \frac{B_n''\left[\frac{b}{a}y+R\left(1-\frac{b}{a}\right)\right]T_{n+2}\left[\frac{\frac{b}{a}(y-x)+R}{R}\right]dy}{\sqrt{R^2-\left[\frac{b}{a}(y-x)+R\right]^2}}=$$

$$=\alpha_n\left(\frac{x-R}{a}\right)-i\beta_n\left(\frac{x-R}{a}\right).$$

The function $T_n(x)=\cos(n\arccos x)$ is the Tchebyshev's polynomial.

Denoting $B_n''\left[\frac{b}{a}y+R\left(1-\frac{b}{a}\right)\right]=\overline{B}_n(y)$ we obtain a system of integral equations (9) of the first order of the Volterra's type with a nucleus depending on the difference of arguments. Effecting the Laplace's transformation on equations (9), we multiply both parts by e^{-sx} and integrate from $x=R$ to $x=\infty$.

Supposing that

$$\int_R^\infty e^{-sy}A_n''(y)\,dy=\overset{*}{\varphi}{}^1(s),\quad \int_R^\infty e^{-sy}\overline{B}_n(y)\,dy=\overset{*}{\varphi}{}^2(s), \qquad (10)$$

$$\left.\begin{aligned}\int_R^\infty e^{-sx}\left[\alpha_n\left(\frac{x-R}{a}\right)-i\beta_n\left(\frac{x-R}{a}\right)\right]dx=f'(s);\\ \int_R^\infty e^{-sx}\left[\alpha_n\left(\frac{x-R}{a}\right)+i\beta_n\left(\frac{x-R}{a}\right)\right]dx=f^2(s),\end{aligned}\right\} \qquad (11)$$

$$\int_R^\infty e^{-sz}K_l^m(z)\,dz=\overset{*}{K}{}_l^m(s)\qquad (l=1,\ 2;\ m=1,\ 2), \qquad (12)$$

where functions $K_l^m(z)$ are the nuclei of the system of integral equations (9), we obtain:

$$\overset{*}{K}{}_l^m(s)\overset{*}{\varphi}{}^l(s)=f^m(s) \qquad (13)$$

and the determinant of this system

$$\Delta s=\|\overset{*}{K}{}_l^m(s)\|$$

in the interval under consideration is different from zero.

Denoting by Φ_p^l the elements of matrix $\Delta^{-1}(s)$, inverse of the matrix Δs, we get the solution of the system (13) in the form:

$$\overset{*}{\varphi}{}^{l}(s) = \Phi_p^l(s) f^p(s). \tag{14}$$

Therefore, by means of the Riemann-Mellin's formula, we obtain from equation (10) the sought functions $A_n''(y)$ and $\overline{B}_n(y)$:

$$\left.\begin{aligned} A_n''(y) &= \frac{1}{2\pi i}\int_{\delta-i\infty}^{\delta+i\infty} e^{ys}\Phi_p^1(s) f^p(s)\, ds, \\ \overline{B}_n(y) &= \frac{1}{2\pi i}\int_{\delta-i\infty}^{\delta+i\infty} e^{ys}\Phi_p^2(s) f^p(s)\, ds. \end{aligned}\right\} \tag{15}$$

Exactly in the same manner as were determined functions $A_n''(y)$ and $\overline{B}_n(y)$ for $R \leqslant y \leqslant 2R$, we can determine them for $2R \leqslant y \leqslant 3R$. For this purpose it is necessary to take into account only the effect of waves reflection. Considering the change of the variable t in the interval $\frac{R}{a} \leqslant t \leqslant \frac{2R}{a}$, let us divide the intervals of integration $(-R+at;\ R+at)$ and $(-R+bt;\ R+bt)$ by the intervals $(-R+at;\ 2R)$ and $(2R;\ R+at)$; $\left[-R+bt;\ R\left(1+\frac{b}{a}\right)\right]$ and $\left[R\left(1+\frac{b}{a}\right);\ R+bt\right]$. To the given boundary conditions add, to the left side of the obtained integral equations, the new members depending on the reflected waves. We act in the same manner for the other instants. Hence, functions $A_n''(y)$ and $B_n''(y)$ are determined in the entire interval of change of y. Integrating we find $A_n(y)$ and $B_n(y)$:

$$A_n(y) = \int_{-R}^{y}(y-\xi)\, A_n''(\xi)\, d\xi; \quad B_n(y) = \int_{-R}^{y}(y-\xi)\, B_n''(\xi)\, d\xi.$$

Without loosing the generality, we can put the coefficients of the polynomials of the first degree equal to zero.

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MÉCANIQUE

SOLUTION DU PROBLÈME PLAN DE L'ÉLASTICITÉ DES CORPS ANISOTROPES POUR L'INTÉRIEUR DE L'ELLIPSE

Par S. LECHNITSKY

(Présenté par A. N. Krylov, de l'Académie, le 8. V. 1937)

1. La solution du problème plan de l'élasticité pour un domaine limité S d'un corps anisotrope et homogène se réduit à la recherche de deux fonctions $\Phi_1(z_1)$ et $\Phi_2(z_2)$ des variables complexes $z_1 = x_1 + iy_1 = x + \mu_1 y$, $z_2 = x_2 + iy_2 = x + \mu_2 y$, holomorphes dans les domaines S_1 et S_2, qu'on obtient de S par la déformation homogène du plan [x, y sont les coordonnées du domaine S, $\mu_1 = \alpha + \beta i$, $\mu_2 = \gamma + \delta i$—des quantités complexes déterminées par les constantes d'élasticité du matériel (1)]. Supposons $\mu_1 \neq \mu_2$, $\beta > 0$ et $\delta > 0$.

Pour le premier problème fondamental d'élasticité, quand les projections des tensions extérieures X_n et Y_n sont données, les conditions aux limites ont la forme:

$$\left.\begin{aligned} 2R\,[\Phi_1(z_1') + \Phi_2(z_2')] &= f_1(x', y') + a', \\ 2R\,[\mu_1\Phi_1(z_1') + \mu_2\Phi_2(z_2')] &= f_2(x', y') + a'', \end{aligned}\right\} \qquad (1.1)$$

où x', y' sont les coordonnées des points sur le contour L du domaine S; z_1', z_2', les points des contours L_1 et L_2 des domaines S_1 et S_2; $f_1 = -\int_0^s Y_n\,ds$, $f_2 = \int_0^s X_n\,ds$, a', a'' sont des constantes arbitraires.

S. G. Michlin a démontré que dans le cas d'un domaine simplement connexe le problème a une solution unique, si le vecteur principal et le moment principal des forces extérieures sont nuls (2).

2. Supposons que le domaine S est l'intérieur de l'ellipse à demi-axes a et b *.

Admettons que l'origine des coordonnées est au centre de l'ellipse et les axes des coordonnées sont dirigés le long des demi-axes; on aura pour l'ellipse:

$$x = a\cos\vartheta, \quad y = b\sin\vartheta. \qquad (2.1)$$

Les équations pour L_1 et L_2, exprimées par le même paramètre ϑ, seront:

$$\left.\begin{aligned} x_1 &= a\cos\vartheta + \alpha b\sin\vartheta, \quad y_1 = \beta b\sin\vartheta, \\ x_2 &= a\cos\vartheta + \gamma b\sin\vartheta, \quad y_2 = \delta b\sin\vartheta. \end{aligned}\right\} \qquad (2.2)$$

* La résolution du problème pour l'intérieur d'une ellipse isotrope est obtenue par N. I. Mouskelichvili (3).

Les tensions données X_n, Y_n peuvent être regardées comme fonctions du paramètre ϑ. En état d'équilibre le vecteur principal doit être nul et l'on obtient:

$$\left.\begin{aligned} f_1 = \alpha_0 + \sum_{m=1}^{\infty}(\alpha_m \sigma^m + \overline{\alpha}_m \sigma^{-m}), \quad f_2 = \beta_0 + \sum_{m=1}^{\infty}(\beta_m \sigma^m + \overline{\beta}_m \sigma^{-m}) \\ (\sigma = e^{\vartheta i}). \end{aligned}\right\} \quad (2.3)$$

Supposons que les séries (2.3) convergent absolument et uniformément sur tout le contour L.

Une fonction $F(z)$ $(z = x + iy)$, holomorphe dans un domaine simplement connexe, limité par un contour simple, peut être représentée à l'aide des polynômes de Faber $P_m(z)$; pour les domaines S_1 et S_2 ces polynômes ont la forme[4]:

$$\left.\begin{aligned} P_{1m}(z) = -\frac{1}{(a - i\mu_1 b)^m}\left\{\left[z_1 - \sqrt{z_1^2 - a^2 - \mu_1^2 b^2}\right]^m + \right. \\ \left. + \left[z_1 + \sqrt{z_1^2 - a^2 - \mu_1^2 b^2}\right]^m \right\}, \\ P_{2m}(z_2) = -\frac{1}{(a - i\mu_2 b)^m}\left\{\left[z_2 - \sqrt{z_2^2 - a^2 - \mu_2^2 b^2}\right]^m + \right. \\ \left. + \left[z_2 + \sqrt{z_2^2 - a^2 - \mu_2^2 b^2}\right]^m \right\}. \end{aligned}\right\} \quad (2.4)$$

Sur les contours L_1 et L_2, quand $z_1 = z_1' = a\cos\vartheta + \mu_1 b \sin\vartheta$, $z_2 = z_2' = a\cos\vartheta + \mu_2 b \sin\vartheta$, on a:

$$\left.\begin{aligned} P_{1m}(z_1') = -\sigma^m - \left(\frac{a + i\mu_1 b}{a - i\mu_1 b}\right)^m \sigma^{-m}, \\ P_{2m}(z_2') = -\sigma^m - \left(\frac{a + i\mu_2 b}{a - i\mu_2 b}\right)^m \sigma^{-m}. \end{aligned}\right\} \quad (2.5)$$

3. Posons:

$$\left.\begin{aligned} \Phi_{1m}(z_1) = A_0 + A_1 z_1 + \sum_{m=2}^{\infty} A_m P_{1m}(z_1), \\ \Phi_{2m}(z_2) = B_0 + B_1 z_2 + \sum_{m=2}^{\infty} B_m P_{2m}(z_2), \end{aligned}\right\} \quad (3.1)$$

et déterminons les coefficients A_m et B_m *.

Il suit de (1.1), où f_1 et f_2 sont déterminées par les séries (3.1), qu'on a les équations suivantes pour déterminer A_m et B_m (on a pour chaque m son système spécial):

$$\left.\begin{aligned} A_m + B_m + \overline{A}_m r_1^m e^{-m\varphi_1 i} + \overline{B}_m r_2^m e^{-m\varphi_2 i} = -\alpha_m, \\ A_m \mu_1 + B_m \mu_2 + \overline{A}_m \overline{\mu}_1 r_1^m e^{-m\varphi_1 i} + \overline{B}_m \overline{\mu}_2 r_2^m e^{-m\varphi_2 i} = -\beta_m, \\ A_m r_1^m e^{m\varphi_1 i} + B_m r_2^m e^{m\varphi_2 i} + \overline{A}_m + \overline{B}_m = -\overline{\alpha}_m, \\ A_m \mu_1 r_1^m e^{m\varphi_1 i} + B_m \mu_2 r_2^m e^{m\varphi_2 i} + \overline{A}_m \overline{\mu}_1 + \overline{B}_m \overline{\mu}_2 = -\overline{\beta}_m, \end{aligned}\right\} \quad (3.2)$$

où

$$r_1 = \left|\frac{a + i\mu_1 b}{a - i\mu_1 b}\right| < 1, \quad r_2 = \left|\frac{a + i\mu_2 b}{a - i\mu_2 b}\right| < 1,$$
$$\varphi_1 = \arg\left(\frac{a + i\mu_1 b}{a - i\mu_1 b}\right), \quad \varphi_2 = \arg\left(\frac{a + i\mu_2 b}{a - i\mu_2 b}\right);$$

* z_1 et z_2 ne diffèrent de $P_{11}(z_1)$ et $P_{21}(z_2)$ que par des coefficients constants.

$$\left.\begin{aligned}
&A_1(a-i\mu_1 b)+B_1(a-i\mu_2 b)+\overline{A}_1(a-i\overline{\mu}_1 b)+\\
&\quad+\overline{B}_1(a-i\overline{\mu}_2 b)=2\alpha_1,\\
&A_1\mu_1(a-i\mu_1 b)+B_1\mu_2(a-i\mu_2 b)+\overline{A}_1\overline{\mu}_1(a-i\overline{\mu}_1 b)+\\
&\quad+\overline{B}_1\overline{\mu}_2(a-i\overline{\mu}_2 b)=2\beta_1,\\
&A_1(a+i\mu_1 b)+B_1(a+i\mu_2 b)+\overline{A}_1(a+i\overline{\mu}_1 b)+\\
&\quad+\overline{B}_1(a+i\overline{\mu}_2 b)=2\overline{\alpha}_1,\\
&A_1\mu_1(a+i\mu_1 b)+B_1\mu_2(a+i\mu_2 b)+\overline{A}_1\overline{\mu}_1(a+i\overline{\mu}_1 b)+\\
&\quad+\overline{B}_1\overline{\mu}_2(a+i\overline{\mu}_2 b)=2\overline{\beta}_1.
\end{aligned}\right\}\tag{3.3}$$

Quelques transformations élémentaires réduisent le système (3.3) à la forme:

$$\left.\begin{aligned}
&A_1\mu_1^2+B_1\mu_2^2+\overline{A}_1\overline{\mu}_1^2+\overline{B}_1\overline{\mu}_2^2=\frac{\overline{\beta}_1-\beta_1}{bi},\\
&A_1+B_1+\overline{A}_1+\overline{B}_1=\frac{\alpha_1+\overline{\alpha}_1}{a},\\
&-(A_1\mu_1+B_1\mu_2+\overline{A}_1\overline{\mu}_1+\overline{B}_1\overline{\mu}_2)=\frac{\alpha_1-\overline{\alpha}_1}{bi},\\
&-(A_1\mu_1+B_1\mu_2+\overline{A}_1\overline{\mu}_1+\overline{B}_1\overline{\mu}_2)=-\frac{\beta_1+\overline{\beta}_1}{a}.
\end{aligned}\right\}\tag{3.4}$$

Ce système a des solutions seulement dans le cas

$$\frac{\overline{\alpha}_1-\alpha_1}{bi}=\frac{\beta_1+\overline{\beta}_1}{a}.\tag{3.5}$$

La condition (3.5) exprime évidemment le fait que le moment principal doit être nul.

Si la condition (3.5) est vérifiée, on obtient du système (3.4) les tensions (5) pour les valeurs α_1, β_1 de (2.3):

$$X_x^{(1)}=\frac{\overline{\beta}_1-\beta_1}{bi},\quad Y_y^{(1)}=\frac{\alpha_1+\overline{\alpha}_1}{a},\quad X_y^{(1)}=\frac{\alpha_1-\overline{\alpha}_1}{bi}.\tag{3.6}$$

Les déplacements $u^{(1)}$, $v^{(1)}$ sont déterminés à un déplacement cynématique du corps près.

Le déterminant Δ_m du système (3.2) ne peut être nul pour $m\geqslant 2$ (si $\mu_1\neq\mu_2$). Supposons que pour $m=m'\geqslant 2$ on a $\Delta_m=0$. Posons $X_n=Y_n=0$; nous verrons que le système (3.2) a une solution non nulle et, par conséquent, il existe un état élastique sans forces extérieures, ce qui contredit le théorème de l'unicité.

Résolvant le système (3.2) nous avons:

$$\left.\begin{aligned}
A_m&=-\frac{1}{\Delta_m}[\alpha_m\delta_{1m}-\beta_m\delta_{2m}+\overline{\alpha}_1\delta_{3m}-\overline{\beta}_m\delta_{4m}],\\
B_m&=-\frac{1}{\Delta_m}[-\alpha_m\delta_{5m}+\beta_m\delta_{6m}-\overline{\alpha}_1\delta_{7m}+\overline{\beta}_m\delta_{8m}],
\end{aligned}\right\}\tag{3.7}$$

où

$$\begin{aligned}
\Delta_m=&[(\alpha-\gamma)^2+(\beta-\delta)^2](1-r_1^{2m})(1-r_2^{2m})-\\
&-4\beta\delta[r_1^{2m}+r_2^{2m}-2r_1^m r_2^m\cos m(\varphi_1-\varphi_2)]
\end{aligned}$$

est le déterminant du système (3.2), et δ_{km} les mineurs correspondants.

Pour chaque $m \geqslant 2$ $|\Delta_m|$ est borné inférieurement, les mineurs δ_{km} pour chaque $m \geqslant 2$ ont des modules bornés et il est facile à voir qu'ils tendent vers des limites déterminées quand $m \to \infty$. Il en résulte que sur les contours L_1 et L_2 les fonctions $\Phi_1(z_1)$ et $\Phi_2(z_2)$ sont développables en séries uniformément convergentes et, par conséquent, les séries (3.1) sont uniformément convergentes dans les domaines fermés S_1 et S_2.

Donc le problème est résolu.

Le second problème fondamental d'élasticité se résoud de la même manière.

Comme cas particulier on obtient la résolution du problème pour un cercle, quand $b = a$, $\vartheta = \theta$ (θ—angle polaire).

La résolution pour un cercle ne devient pas plus simple que pour une ellipse contrairement au cas du problème plan d'un corps isotrope.

Institut de Mathématiques et de
Mécanique de l'Université.
Léningrad.

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MÉCANIQUE CÉLESTE

SUR LES TRAJECTOIRES PÉRIODIQUES AUTOUR DU POINT DE LIBRATION L_1 DANS LE PROBLÈME DES TROIS CORPS DE COPENHAGUE

Par N. MOÏSEIEV

(Présenté par B. Fessenkov, de l'Académie, le 9. V. 1937)

Dans un de nos articles précédents (1) nous avons démontré pour un problème dynamique à deux degrés de liberté un théorème sur l'existence des trajectoires ne coupant pas la frontière d'un domaine donné. Dans le cas particulier, où le domaine est un anneau, le théorème mentionné coïncide avec le critère de l'existence d'une trajectoire périodique, critère énoncé par Whittaker (2) en 1902 et resté jusqu'à présent sans démonstration générale, aussi bien que sans aucune application aux problèmes de la dynamique. En continuant nos esssais sur l'application de ce critère, commencés par notre article «Sur quelques classes des orbites périodiques» (3), nous donnons ici encore un exemple de l'usage du critère de Whittaker dans la forme que nous lui avons donné.

Il est bien connu qu'il existe dans le problème restreint des trois corps une famille uniparamétrique de trajectoires périodiques autour du point de libration L_1. L'existence de cette famille, qui est évidente dans la première approximation, peut être rigoureusement démontrée à l'aide des méthodes de A. Liapounoff. On est amené au même résultat par les recherches numériques de Strömgren, qui a étudié avec tant de succès le développement de la classe «c» des orbites périodiques dans le problème de Copenhague. Nous montrons dans le présent article que la théorie basée sur le critère de Whittaker nous fournit encore un moyen très simple pour la résolution du même problème, tout à fait différent des moyens déjà employés.

En employant des notations usuelles (4) nous écrivons les équations différentielles du mouvement dans le problème de Copenhague sous la forme:

$$\left.\begin{aligned} \ddot{x} &= 2\dot{y} + U'_x, \\ \ddot{y} &= -2\dot{x} + U'_y, \end{aligned}\right\} \tag{1}$$

où

$$\left.\begin{aligned} U &= \frac{r^2}{2} + \frac{1}{2r_1} + \frac{1}{2r_2};\quad r^2 = x^2 + y^2;\quad r_1^2 = (x+0.5)^2 + y^2; \\ & r_2^2 = (x-0.5)^2 + y^2. \end{aligned}\right\} \tag{2}$$

Pour le cas du mouvement dans le voisinage du point $L_1(x = y = 0)$ les équations (1) peuvent être transcrites comme il suit:

$$\left.\begin{aligned} \ddot{x} &= 2\dot{y} + 17x + X_2, \\ \ddot{y} &= -2\dot{x} - 7y + Y_2, \end{aligned}\right\} \tag{3}$$

où X_2 et Y_2 sont des fonctions holomorphes de x et de y, dont les développements suivant les puissances entières et positives de x et de y commencent par des termes de second degré. La forme correspondante de l'intégrale de Jacobi est:

$$\rho^2 = \dot{x}^2 + \dot{y}^2 = 2\left[h + 2 + \frac{17x^2 - 7y^2}{2} + U_3\right], \tag{4}$$

où U_3 est une fonction holomorphe des variables x et y, dont le développement commence par des termes de troisième degré.

Nous envisageons la famille topographique des ellipses

$$a^2x^2 + y^2 = f, \tag{5}$$

où f est un paramètre et a est une constante réelle, dont nous choisirons la valeur un peu plus tard. Le lieu géométrique des contacts d'ordre supérieur à 2 des trajectoires de la famille isoénergétique (h) du problème (2) et des ellipses (5), ou, si l'on veut, l'osculatrice $f^0_{\pm}(h)$, possède l'équation suivante:

$$h = -U + \frac{P^2}{2S^2}[P^2 \pm \sqrt{H}]^2, \tag{6}$$

où

$$\left.\begin{aligned} P^2 &= f_x'^2 + f_y'^2; \quad Q = U_x'f_x' + U_y'f_y'; \\ S &= f_{xx}''f_y'^2 - 2f_{xy}''f_x'f_y' + f_{yy}''f_x'^2; \quad H = P^4 - QS. \end{aligned}\right\} \tag{7}$$

En remarquant que le second membre de l'équation (6) est une fonction holomorphe de la variable $\sqrt{f}$, dont les coefficients du développement suivant les puissances de $\sqrt{f}$ sont des fonctions algébriques de $\cos\vartheta = \frac{x}{r}$ et de $\sin\vartheta = \frac{y}{r}$ et à variation bornée, nous écrivons l'équation (6) sous la forme

$$H \equiv h + 2 = f\left\{\frac{F_{\pm}(\vartheta)}{\Phi(\vartheta)} + \Psi(\vartheta, f)\cdot\sqrt{f}\right\}, \tag{8}$$

où

$$\begin{aligned} F_{\pm}(\vartheta) = {} & a^4(a^2\cos^2\vartheta + \sin^2\vartheta)^2(7\sin^2\vartheta - 17\cos^2\vartheta) + \\ & + (a^4\cos^2\vartheta + \sin^2\vartheta)\left[(a^4\cos^2\vartheta + \sin^2\vartheta) + \right. \\ & \left. + \sqrt{a^6(a^2 - 17)\cos^4\vartheta - 8a^4\cos^2\vartheta\sin^2\vartheta + (7a^2 + 1)\sin^4\vartheta}\right]^2 \end{aligned} \tag{9}$$

et

$$\Phi(\vartheta) = 2a^4(a^2\cos^2\vartheta + \sin^2\vartheta)^3, \tag{10}$$

tandis que Ψ est une fonction holomorphe de $\sqrt{f}$ dont les coefficients du développement suivant les puissances de $\sqrt{f}$ sont des fonctions algébriques de $\sin\vartheta$ et $\cos\vartheta$ et à variation bornée. En envisageant la fonction (9) nous pouvons arriver sans peine à la conclusion suivante: il est toujours possible de choisir la valeur de a telle, que la fonction $F_+(\vartheta)$, ainsi que la fonction $F_-(\vartheta)$ surpassent un certain nombre positif pour chaque valeur possible de ϑ. [Il suffit de prendre pour cela a^2 plus grand que $a_c^2 = \frac{1}{7}(67 + \sqrt{4608}) \approx 19.2689$].

Alors, pour le nombre a ainsi choisi l'équation (8), considérée comme une équation en $\sqrt{f}$, en supposant que ϑ a une valeur fixe, possède deux et seulement deux racines positives, une dans le cas où $F_{\pm} = F_{+}$, et l'autre dans le cas où $F_{\pm} = F_{-}$, tous les deux satisfaisant à la condition que la valeur de f peut être rendue aussi petite que l'on veut par un choix convenable de la valeur positive et assez petite de $H = h + 2$. Ces racines sont holomorphes en $\sqrt{H}$ et peuvent être représentées par la formule:

$$f = H \cdot G_{2\pm}(\vartheta) + H^{3/2} \cdot G_{3\pm}(\vartheta) + \ldots, \tag{11}$$

où

$$G_{2\pm}(\vartheta) = \frac{\Phi(\vartheta)}{F_{\pm}(\vartheta)} \tag{12}$$

ainsi que tous les autres coefficients sont des fonctions périodiques de ϑ et à variation bornée. Il en suit que, pour a choisi d'une manière convenable, on peut toujours indiquer une valeur positive H_a telle que pour chaque H de l'intervalle

$$0 < H < H_a \tag{13}$$

il existe autour de L_1 deux et seulement deux branches simples et fermées de l'osculatrice $\ddot{f}^0_{\pm}(h)$, n'ayant pas de points communs, entourant L_1 et dégénérant en L_1 même pour $H \to 0$. De ces deux branches celle qui est intérieure ($G_{\pm} = G_{+}$) correspond à la branche $\ddot{f}^0_{-}(h)$ de l'osculatrice, c'est-à-dire, au cas du mouvement synodique rétrograde [cf. p. 169 de l'article consacré au problème de Copenhague (4)]. En remarquant que dans le problème envisagé chaque branche de la courbe de vitesse zéro $v^0(h)$, a pour chaque valeur de h, des points éloignés à distance finie de L_1 et que l'osculatrice $\ddot{f}^0_{\pm}(h)$ ne peut pas couper la courbe $v^0(h)$, nous pouvons conclure que des deux branches de l'osculatrice celle qui est extérieure ($G_{\pm} = G_{-}$) ne contient à son intérieur aucun point du domaine de mouvement impossible $v^2(h) < 0$.

Pour en finir avec les remarques préliminaires il nous suffit de montrer, que les valeurs a et H_a peuvent être choisies de telle manière que, pour chaque H de l'intervalle (13), il existe parmis les ellipses (5) des ellipses qui séparent les deux branches de l'osculatrice $\ddot{f}^0_{\pm}(h)$ (11), précédemment indiquées, et qui n'ont aucun point commun avec ces branches. Or, cette dernière affirmation serait demontrée, si nous pourrions nous convaincre que la valeur de a peut être choisie de telle manière que la plus grande des valeurs maxima de la fonction

$$G_{2+}(\vartheta) = \frac{\Phi(\vartheta)}{F_{+}(\vartheta)} \tag{14}$$

ne surpasse pas la plus petite des valeurs minima de la fonction

$$G_{2-}(\vartheta) = \frac{\Phi(\vartheta)}{F_{-}(\vartheta)}. \tag{15}$$

Cette question peut être résolue d'une manière purement analytique. Ne voulant pas encombrer notre note préliminaire par des calculs élémentaires et longs nous préférons de donner ici au lieu d'une démonstration analytique les résultats des calculs numériques. La table suivante, calculée par T. Vodopianova, nous montre que l'affirmation énoncée est déjà exacte pour la valeur de a^2 égale à 20.

En admettant que les nombres de cette table sont exacts et en résumant tout ce qui précède nous arrivons à la conclusion suivante:

Table

	$a^2 = a_c^2 = 19.2689$		$a^2 = 20.0000$	
	G_{2+}	G_{2-}	G_{2+}	G_{2-}
Minimum minimorum	0.059032	0.269126	0.053132	0.274137
Maximum maximorum	0.269126	0.476	0.269746	0.477

Il existe dans le problème de Copenhague un intervalle de valeurs de H (13) tel qu'à chaque H de cet intervalle et à un système d'ellipses (5), convenablement choisi, corresponde une branche de l'osculatrice $\ddot{f}_-^0(h)$ qui est simple, fermée, régulière, isolée sur le système topographique (5), qui entoure le point L_1 et qui admette une simple transformation en chacune des ellipses (5), ayant avec cette branche des points communs.

Cette conclusion, étant comparée avec les conditions du théorème sur l'existence des trajectoires, que nous avons mentionné au commencement de la note [il faut d'ailleurs employer la rédaction B de ce théorème, voir l'introduction à l'article cité (3)], nous amène au resultat final.

Il existe dans le problème de Copenhague un intervalle de valeurs de H (13), tel qu'à chaque H de cette intervalle corresponde une (au moins) trajectoire, qui est périodique, simple, régulière, qui entoure L_1, qui est parcourue dans la direction rétrograde du mouvement synodique et qui n'a pas de points situés hors de l'anneau limité par deux ellipses du système

$$20x^2 + y^2 = f \tag{16}$$

correspondant respectivement aux deux valeurs suivantes du paramètre f:

$$f_m = 0.053132\,H + (\text{les termes d'ordre supérieur par rapport à } H), \tag{17}$$

$$f_M = 0.269746\,H + (\text{les termes d'ordre supérieur par rapport à } H). \tag{18}$$

Le domaine annulaire que nous venons de citer est un domaine de Whittaker. La considération du signe que la caractéristique de contact $\ddot{f}_-(h)$ admet sur la frontière du domaine, c'est-à-dire sur les courbes (16), (17) et (16), (18), nous montre que le domaine lui même appartient au premier type. Par conséquent, la trajectoire périodique conjuguée à ce domaine au moyen du système topographique (16) doit être stable au sens de Jacobi (1, 3). Ce qui précède nous fournit une démonstration nouvelle de l'existence d'une famille de trajectoires périodiques autour du point L_1. Il est très probable que cette famille coïncide avec la famille dont l'existence a été demontrée par A. Liapounoff et laquelle à son tour semble n'être autre chose que la classe «c» de Strömgren. Mais malgré toute la vraisemblance de cette identification, elle ne peut pas encore être considérée comme un fait bien établi.

Quant à la classe des orbites périodiques de la première approximation, elle est dans ce cas représentée par la famille des ellipses:

$$a_c^2 x^2 + y^2 = H \cdot \frac{2a_c^2(a_c^2 - 1)}{17 + 7a_c^4}. \tag{19}$$

Remarquons, en concluant notre note, que la question sur l'existence des orbites périodiques autour des autres points de libration peut être résolue d'une manière tout à fait analogue, et il en est de même dans le cas général du problème restreint des trois corps.

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PHYSIQUE

SUR LES VARIATIONS DE L'INTENSITÉ DES RAIES DU TITANE ET DU VANADIUM À L'INTRODUCTION DANS L'ARC ÉLECTRIQUE DES SELS DE NA ET DE K

Par S. A. BOROVIK et T. T. BOROVIK-ROMANOVA

(Présenté par S. I. Wawilow, de l'Académie, le 23. IV. 1937)

Dans la pratique de l'analyse spectrale des minéraux à l'aide de l'arc électrique la pureté des électrodes en charbon employées joue un rôle important. Les charbons du commerce ordinaires ne sont pas assez purs. Goldschmidt(1) et d'autres auteurs(2) ont montré la nécessité de calciner les charbons à haute température (2500°), cependant ce traitement n'est pas capable d'éloigner entièrement les impuretés. Ce qui entrave le plus les analyses ce sont les raies de certains éléments qui font défaut dans le spectre des charbons purs et apparaissent ou bien augmentent leur intensité à l'introduction dans l'arc de l'une et de l'autre matière. Nous avons obtenu nos données en travaillant avec des électrodes de charbon pour étudier la conduite des raies du titane et avec des électrodes de graphite qui contenaient outre Fe, Si, Ti, Cu 0.00392% de vanadium; les électrodes de graphite ont été employées dans les expériments sur les raies du vanadium. Les électrodes en charbon préparées par l'usine de Koudinovo ont été calcinées d'après la méthode de Rousanov(3). On photographiait les spectres à l'aide du spectrographe en quartz de Hilger, modèle moyen. On se servait de l'arc continu à intensité 7 A et à tension 110 V. L'image agrandie de la flamme de l'arc a été projetée sur un diaphragme qui laissait passer sur la fente du spectrographe une petite portion du milieu de l'arc. Les matières à analyser ont été introduites dans le trou de l'électrode inférieure de 5 mm de profondeur et de 2 mm de diamètre.

Pour mesurer l'intensité des raies nous nous sommes servis du microphotomètre de Krüss. Les chiffres donnés dans les tables ont été comptés sur l'échelle électrométrique prenant pour zéro la déclinaison de l'électromètre produite par le fond de la photographie; celui-ci possédant près des raies à mesurer la même intensité.

Arrêtons nous tout d'abord sur les raies du titane. Les résultats obtenus par la lecture des spectrogrammes présentant l'intensité des raies principales du titan, sont donnés dans la table 1. Dans les colonnes de cette table est donnée l'intensité des raies du titane obtenues avec des charbons purs et de celles obtenues à l'introduction de KCl, NaCl, Pb_3O_4, SiO_2, K_2CO_3, ces matières ayant été d'une pureté exceptionelle et exemptes de titane. Les deux dernières colonnes donnent l'intensité d'après les tableaux de Kaiser. Sous la lettre *R* il faut entendre la capacité d'autoinversion de la raie; sous

le signe I, l'appartenance de la raie à l'atome neutral, et sous le signe II l'appartenance à l'atome ionisé.

Table 1

	Charbons purs	L'intensité à l'introduction dans l'arc					Longueur d'onde en Å	Intensité d'après les tableaux	
		KCl	NaCl	Pb_3O_4	SiO_2	K_2CO_3		en l'arc	en étincelle
Ti_I	—	34	37	7	24	24	3371.5	9 *R*	2
»	—	28	28	4	15	13	3186.5	9 *R*	3
»	—	33	32	3	19	17	3192.0	9 *R*	1
»	—	37	35	4	23	21	3199.0	9 *R*	3
Ti_{II}	19	—	19	18	31	15	3372.8	10	10 *R*
»	26	8	38	23	40	21	3361.2	8 *R*	10
»	37	12	41	27	45	25	3349.4	9 *R*	10 *R*
»	15	17	34	18	36	16	3234.5	8 *R*	10 *R*

À l'étude des données de cette table l'on est frappé tout d'abord par la différence dans la conduite entre les raies de l'atome ionisé et de celui non-ionisé. Tandis que l'intensité des premières est presque invariable, celle des dernières augmente considérablement. L'effet le plus marqué est obtenu à l'introduction de KCl et de NaCl; Pb_3O_4 agit le moins. Dans le cas des charbons purs les raies de l'atome neutre (arc) sont absentes sur le cliché; on voit un trait [—] dans la table. Cet effet saute surtout aux yeux dans l'exemple des raies du Ti_I 3371.5 et T_{II} 3372.8 qui sont placées très proches l'une de l'autre.

La conduite des raies du vanadium est donnée dans la table 2.

Table 2

Électrodes de graphite pur	Intensité à l'introduction de		Élément et son état	Longueur d'onde en Å	Intensité d'après les tableaux	
	NaCl	KCl			en arc	en étincelle
5	32	26	V_I	3183.4	10 *R*	2 *R*
8	36	26	»	3183.99	10 *R*	2 *R*
8	34	23	»	3185.4	10 *R*	2 *R*
17	18	7	V_{II}	3093.1	4	10 *R*
14	14	6	»	3102.3	10	10 *R*
9	11	3	»	3110.7	8	10 *R*
10	9	3	»	3118.4	10 *R*	10 *R*
9	7	2	»	3125.3	8	2

Ici se repète le même tableau; avant l'introduction de la substance dans les électrodes de graphite les raies de V_I sont sensiblement plu faibles

que les raies du V_{II}; KCl affaiblit les raies du V_{II} et intensifie considérablement les raies de V_I; NaCl n'attenue pas les raies de V_{II}, mais intensifie également les raies de l'atome pur du vanadium. En ce qui concerne la quantité, les contrastes y sont moins grands tandis qu'au point de vue de la qualité il y a ici une coïncidence avec ce qui a été observé sur les raies du titane dans les électrodes en charbon. La comparaison des intensités observées de nos spectrogrammes avec celles des tableaux a démontré une parfaite concordance de la valeur relative de l'intensité des raies d'arc entre eux et des raies d'étincelles, en particulier, tandis que la comparaison des raies de l'atome neutre et de l'atome ionisé n'a montré aucune concordance.

Outre les raies du titan et du vanadium est à noter la conduite des raies du carbon fort bien représentée par nos spectrogrammes. Il est à regretter que nous ne possédons qu'une seule raie de l'atome ionisé C_{II}, $\lambda = 2478.6$ Å, ce qui fait impossible de comparer sa conduite à celle d'autres raies et induit à se borner de valeurs absolues données dans la table 3.

Table 3

Raie de carbon 2478.6 Å dans les charbons calcinés

Charbons purs; photographies répétées				Intensité de la raie du carbon à l'introduction de				
				KCl	NaCl	K_2CO_3	SiO_2	Pb_3O_4
63	66	64	67	14	59	30	59	57

Dans les bâtons de graphite

Électrodes purs		KCl		NaCl		Pb_3O_4	
53	52	14	14	33	36	44	45

La table 3 caractérise la stabilité du flamboyement de l'arc: dans quatre spectrogrammes réitérées nous avons les mêmes chiffres pour l'intensité de la raie du carbon. L'introduction de KCl atténue considérablement l'intensité de cette raie; les mêmes clichés démontrent un accroissement considérable des raies Ti_I de sorte que l'affaiblissement de la raie du carbon ne peut pas être imputable à l'affaiblissement général du spectre.

Les raies du bor 2497.7 et 2496.8 Å montrent la même conduite que la raie du carbon, étant un peu plus faibles que celles-ci dans les charbons purs.

Ce travail a été terminé au décembre 1936; en 1937 dans la «Nature»(4) a été publié l'article de D. A. Webb, qui constate lui aussi l'effet d'accroissement de l'intensité de quelques raies à l'introduction dans l'arc de la

cendre de plantes, mais quant à la différence dans la conduite des raies des atomes ionisé et neutre elle n'y est pas donnée.

Laboratoire de l'Analyse Spectrale.
Institut Lomonosof
Académie des Sciences de l'URSS.

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PHYSICS

THE INFLUENCE OF SURFACE STATE ON THE PLASTICITY OF CRYSTALS

By A. V. STEPANOV

(Communicated by A. Joffe, Member of the Academy, 7. V. 1937)

What is the cause of the plasticity and low elastic limit of crystals?

No satisfactory answer has yet been found to this fundamental question in crystalo-physics.

The results of experiments, very briefly described here, establish one of the factors determining the course of the plastic deformation.

Fig. 1.

Scratches were made on a rectangular specimen of rock salt, and their effect on the process of slip formation during extension was observed in polarized light.

The main result may be summarized in the statement that a scratch is the source of the slip.

The gradual propagation of the slips beyond the region of the scratch, and their extension throughout the bulk of the crystal were observed directly (Fig. 1). The effect was especially pronounced when the scratches were made on specimens, the original surfaces of which had been previously dissolved away. The bright rays on Fig. 1 are artificially produced slips. An examination of the crystal in the region of the scratch before extension showed that a scratch produces not only a surface fault, but also a volume change to a considerable depth of the crystal; it might therefore be surmised that the

Fig. 2.

Fig. 3.

new effect of artificial slip formation is not due to a surface but to a volume change brought about by the scratch.

Experiments conducted to test this possibility gave the following results.

1) A surface fault is in itself a source of slip. [Scratched samples were extended after they had been annealed at 600° C for 6 hours; the effect of the scratches was preserved (Fig. 2).]

2) The volume change brought about by scratching is also a source of slip. (Scratched samples were extended after dissolving away various depths of surface. The effect of the scratch remained after slight errosion but was eliminated by prolonged solution.)

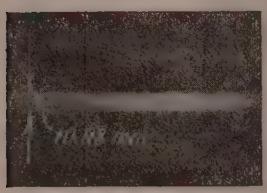

Fig. 4.

The observed picture of artificially produced «slips» depends on the experimental conditions (temperature), depth and method of production of the scratches and the reciprocal action of closely situated scratches. With a large number of scratches the result obtained on an erroded specimen is very similar to that obtained with a dry crystal. By combining and distributing the disturbances on the surface it was possible to obtain at will any desired slip pattern (Fig. 3).

The fact that the process of slip formation depends to such an extent on the state of the surface indicates that surface defects are one of the causes of crystal plasticity. However, the existence of slips in addition to those con-

nected with the surface defects shows that other causes also operate and these may probably be attributed to volume defects.

A number of details in the photographs may be noted, such as 1) the increased illumination in the parts lying along the locus of the intersection of the slips, with a straight line drawn at an angle of 45° to the axis of the specimen from the scratch (Fig. 1, dotted in the upper ray); 2) the direction of the slips deviates considerably from 45° (Fig. 2) etc. Fig. 4 shows part of one of the rays reproduced on Fig. 2, greatly magnified.

It appears that the plastic deformation of crystals cannot be explained by a simple slipping mechanism. The rupture takes place along the scratch.

The process of rupture proceeds as follows: the surface defect gives rise to the appearance of slips which, in their turn, lead to the development of a surface defect which ends in fracture.

In all the photographs reproduced here, the scratches are normal to the plane of the illustration. The arrows indicate their position. The scratches were produced by means of a Marten's sclerometer.

The state of the surface is probably also of importance in twinning. A detailed account of these experiments will shortly be published in the «Phys. Zeits. d. Sowjetunion».

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PHYSICAL CHEMISTRY

ON THE QUESTION OF PRESENCE OF FILMS ON METALS

By E. I. GUROVIČ

(Communicated by V. A. Kistjakovskij, Member of the Academy, 29. IV. 1937)

The film theory of corrosion of metals, as is known, assumes the existence of films on the surface of metals.

A number of indications and proofs of the presence of these films on metals are contained in literature published. Of these works may be pointed out that of Member of the Academy V. A. Kistjakovskij, the founder of the film theory of metals(1), H. Freundlich, G. Patscheke und H. Zocher(2), F. Krüger und E. Nähgring(3), G. P. Thomson(4), U. R. Evans(5), W. H. J. Vernon(6), V. Kohlschütter and E. Krähenbühl(7), U. R. Evans and J. Stockdale(8), F. P. Bowden and E. R. Rideal(9), W. G. Palmer(10) and others.

We present in this work, still another, in our opinion, exceedingly interesting proof of the existence of films on metals. It was V. A. Kistjakovskij who first established that separate corrosion centres form under the action of iodine vapor on the surface of iron.

It is this property of iodine vapor in the formation on the surface of iron of separate corrosion centres which we have utilized in the present work.

Experiments were conducted on the influence of iodine vapor on the surface of polished iron having an oxide film and on the surface of iron without the film, which we removed mechanically under mercury.

It was then discovered that the number of corrosion centres and their dimensions differed considerably in both cases mentioned. This circumstance allows us to draw the conclusion that a film existed on the metallic surface, otherwise we would not have obtained such a pronounced effect in our work.

EXPERIMENTAL PART

1. Apparatus

Fig. 1 shows the apparatus constructed by us and which we used in our researches.

This apparatus consists of a glass vessel *A*, having a polished lid *K* (a highly polished glass disc with polished edge).

As will be seen from the drawing, this vessel has three elbow tubes with taps.

Two of these are inlet tubes (I. T) (for iodine vapor and steam). They are soldered to the vessel near the lid *K*, in order to facilitate the contact of the vapors on the microsection.

The third tube (O. T.)—the outlet tube—is soldered on the bottom of the vessel so that the heavy vapors of iodine may be quickly pumped (with the aid of a vacuum), should this be found necessary during the experiment.

Within the vessel *A* was placed a polished glass cube *C* which served as a table for the microscope. By means of rubber tubing the inlet tubes (I. T.) were connected to vessels: one containing finely powdered iodine and the other a small quantity of water. A tube passed from the centre of the bottom of vessel *A*, connected by a rubber tubing with the reservoir for mercury (*B*) which served as equalizing balloon.

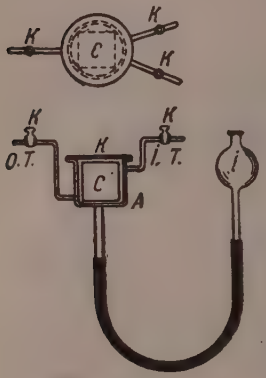

Fig. 1.

2. Methodics of the Work and Experiments

To prevent its rising to the surface in mercury, the glass cube *C* was fixed between the walls of the vessel *A* by means of rubber corks.

The metal microsection which was to be experimented upon was sticked on the cube *C* by means of Mendeleev's lute.

By raising the reservoir (*B*) we filled the vessel *A* to the very edge with mercury, the latter covering likewise the microsection under test.

Prior to the experiments the mercury was specially treated, purified and distilled (in the usual way) and then washed in a jet of hydrogen under heat, to free it of oxygen.

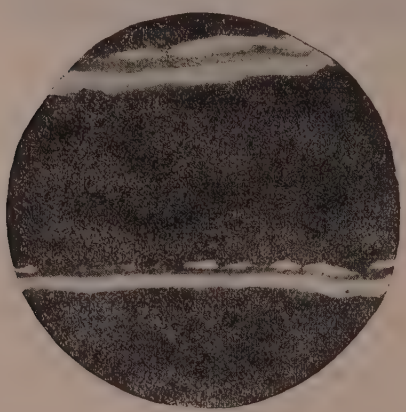

Fig. 2.

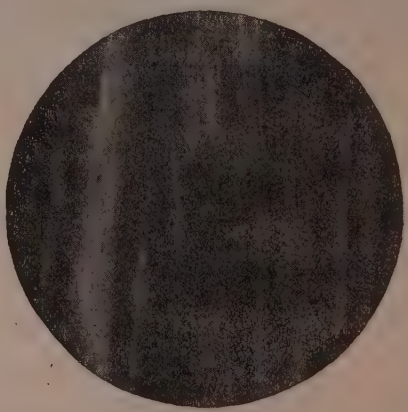

Fig. 3.

After the microsection had been covered by the mercury, either scratching was made on it with a needle (under mercury) or, by a special steel knife, the oxide film was mechanically removed from the microsection. Thereupon, the vessel *A* was covered with the lid, which was smeared with special vacuum lute around its edges; by lowering the reservoir *B*, the mercury was emptied from the vessel *A* (all the taps being kept closed), whereby, naturally, a vacuum was, to some extent, formed in the vessel *A*.

Availing ourselves of this vacuum, we introduced steam and iodine vapor into the vessel *A*, opening the taps of the inlet tubes (I. T.).

Observations were conducted with the aid of a microscope (magnitude—180) furnished with a photomicrographic apparatus with a side tube. Fifteen seconds after being introduced the steam and iodine vapor were removed from the vessel *A* by means of a vacuum pump.

On Fig. 2 were shown the scratches made (under mercury) on iron microsection after it had been subjected to the action of iodine vapor.

It will be seen from the above photograph that the scratches are thickly strewed with separate corrosion centres, whereas the rest of the microsection possesses a comparatively lesser number of corrosion centres.

Fig. 3 shows the surface of the iron microsection the greater part of which was «denuded», i. e. the film was removed with a steel knife.

Fig. 4 represents the same microsection immediately after the action upon it of iodine vapors.

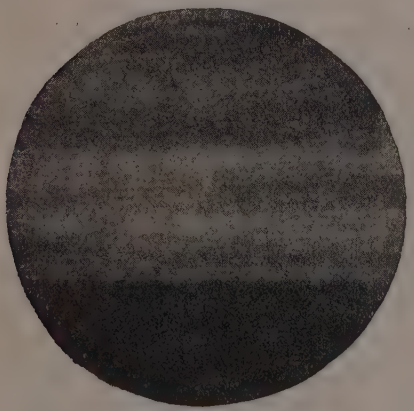

Fig. 4.

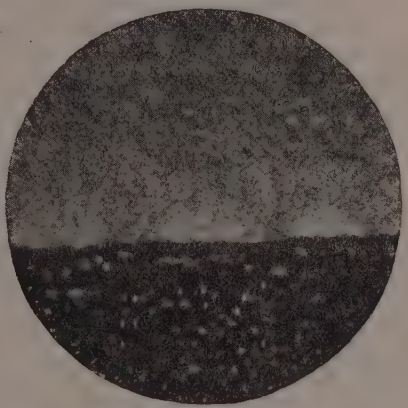

Fig. 5.

We can also see here that the number of corrosion centres on the «denuded» part of the iron surface is far greater than on the untouched part (i. e. still covered by the film).

It should be mentioned here that the dimensions of these corrosion centres on the films are greater than those on the «denuded» part of the metal.

Fig. 5 is of exceptional interest, giving an illustration of the same microsection on the day following the test.

It will be observed from this photograph that, whereas in that part of the microsection where the film was still preserved there still remained separate corrosion centres, in that part where this film had been removed we witness a continuous crust of corrosion products.

These experiments graphically confirm the correctness of the film theory, as otherwise it would not have been possible to discover such a pronounced effect. It is natural that such amplified corrosion on the «denuded» part of the metal surface did not proceed without «solidation» ([11]) of the film.

Iodine vapors caused «solidation» of the film at the moment of its formation.

Its formation commenced at the moment when steam and iodine vapors, and, together with them, air, were admitted into the vessel *A*.

This film may have formed on account of the oxygen from the air and steam.

On this, but thin and insufficiently resistant film, following its formation, the iodine vapors commenced exerting their influence, causing «solidation» of the film at the moment of its formation at the spots where corrosion centres began to appear.

Owing to the fact that this film, newly formed in the manner stated, was not resistant, i. e. possessed a fairly large number of corrosionally weak spots, one can understand the appearance on such a part of the microsection, initially «denuded», of a greater number of corrosion centres against the same effect on a specimen possessing an oxide film.

Conclusions

1. A new proof is given of the presence of films on metals.
2. An apparatus has been constructed which permits the procedure of the action of vapors and gases on the surfaces under study with the simultaneous micro-examination or microphotographing of the surface under study by the absence of oxygen at the beginning of the research.

Colloido-Electrochemical Institute.
Academy of Sciences of the USSR.

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CHEMIE

ÜBER DIE LÖSLICHKEIT VON EDELMETALLEN BEI HOHEM DRUCK

I. DIE AUFLÖSUNG VON PLATINMETALLEN IN SALZSÄURE BEI LUFTDRUCK

Von W. G. TRONEV

(Vorgelegt von N. S. Kurnakow, Mitglied d. Akademie, d. 26. IV. 1937)

In der vorliegenden Mitteilung werden kurz die experimentellen Angaben über die Löslichkeit von Platinmoor und Platinschwamm in Salzsäure bei Luftdruck beschrieben, sowie auch einzelne Versuche über die Löslichkeit von Rhodium und Iridium bei den gleichen Bedingungen angeführt.

In der Literatur wurde schon mehrfach auf die Tatsache der teilweisen Auflösung aller Edelmetalle in Salzsäure in Gegenwart von Luft von Atmosphärendruck hingewiesen, aber über die Anwendung von hohen Lutfdrucken gibt es überhaupt keine Angaben.

So beobachtete Fairley([1]) eine teilweise Auflösung von Au und Pt in Salzsäure. Wilm([2]), Matignon([3]), Mellet([4]), Berthelot([5]), Spring([6]), Hanriot und Raoult([7]), McCaughey([8]) und Vassiljew([11]) stellten eine unbedeutende Auflösung einzelner Edelmetalle in HCl in Gegenwart von Luft fest. Ferner gibt es eine ansehnliche Zahl von Arbeiten, in welchen als Oxydationsmittel bei der Auflösung von Edelmetallen anstelle von Salpetersäure verschiedene, Sauerstoff enthaltende Verbindungen verwendet wurden. So schlug z. B. Zappi([9]) zur Auflösung von Platin anstatt Königswasser ein Gemisch von HCl und $HClO_3$ zu benutzen, Rudnik und Cooke([12]) empfehlen für die Auflösung von ungeglühten Platinmoor ein Gemisch von HCl und H_2O_2; Watts und Whypple([10]) untersuchten die Auflösungsgeschwindigkeit von Au und Pt in verschiedenen Säuren mit Beimengungen der verschiedensten Oxydationsmittel; Ogryzlo([13]) untersuchte die Löslichkeit von Au in HCl und anderen Lösungsmitteln bei hohen Temperaturen und bei 6—7 Atmosphären Druck.

Die Ergebnisse der aufgezählten Arbeiten kann man olgendermassen zusammenfassen: 1. Die Edelmetalle verdrängen nicht den Wasserstoff aus den Säuren, und daher ist zu deren Auflösung die Anwesenheit von Sauerstoff in dieser oder jener Form notwendig. 2. Der Lösungsvorgang dieser hinsichtlich der Säuren besonderen Klasse von Metallen ist ungenügend geklärt. 3. Praktische Ergebnisse, welche in der Praxis eine schnelle und völlige Auflösung der Edelmetalle gestatten würden, sind nicht erzielt worden. 4. Luftdruck, welcher die O_2-Konzentration vergrössert, muss den Auflösungsprozess beschleunigen.

Hiervon ausgehend, schien es von Interesse, die Wirkung der einzelnen Säuren, insbesondere der Salzsäure, auf die Edelmetalle bei hohem Luftdruck zu untersuchen. Bei hohem Druck ist es möglich, die Untersuchung der Wechselwirkung zwischen leichtverdampfenden Flüssigkeiten und fes-

ten Stoffen in einem breiten Temperaturintervall durchzuführen. Folglich hat man die Möglichkeit, nicht nur die Fragen über den Mechanismus der Wirkung des Sauerstoffs bei der Auflösung dieser Metalle zu klären, sondern auch die praktischen Fragen bezüglich der Geschwindigkeit und Vollständigkeit der Auflösung dieser schwer löslichen Metalle, insbesondere in Salzsäure, ohne Verwendung von Salpetersäure und anderen Oxydationsmittel, die durch den Sauerstoff der unter Druck befindlichen Luft ersetzt werden, zu lösen.

I. Versuche über die Löslichkeit von Platin in Salzsäure bei Luftdruck

Bei der Aufstellung dieser Versuche gingen wir davon aus, dass die Auflösung der Edelmetalle in Salzsäure letzten Endes zur Oxydation von HCl durch Sauerstoff unter Bildung von Chlor in stat. nasc. führt, welches bei der Reaktion mit dem Metall gelöste Chloride gibt; d. h. im wesentlichen reduziert sich der Auflösungsmechanismus auf den folgenden Prozess:

$$2HCl + O \rightleftarrows H_2O + Cl_2; \quad Pt + Cl_2 + 2HCl \rightarrow H_2PtCl_6.$$

Hieraus folgt, dass die Faktoren, welche die Auflösungsgeschwindigkeit von Pt in HCl in Gegenwart von Luft bestimmen, folgende sein müssen: 1) Die Grösse der Platinteilchen, die ihre Berührungsoberfläche mit HCl bestimmt. 2) Die HCl-Konzentration. 3) Die O_2-Konzentration oder der Luftdruck. 4) Die Temperatur, die das Gleichgewicht des Dickonschen Prozesses und folglich die Konzentration des aktiven Chlors bestimmt. Weiterhin werden die Versuchsergebnisse über die Untersuchung des Einflusses dieser Faktoren auf die Auflösungsgeschwindigkeit gegeben.

a) Einfluss des Luftdruckes

Die Versuche wurden in einer einfachen Bombe ohne Umrühren ausgeführt. Als Versuchsobjekt zur Auflösung wurde eine abgewogene Menge von im H_2-Strom durchgeglühtem Platinschwamm benutzt, die sich in konzentrierter HCl bei gewöhnlichem atmosphärischem Druck und gewöhnlicher Temperatur praktisch nicht löst. Die abgewogene Menge wurde in ein Probiergläschen mit 26 cm³ starker Salzsäure (spez. Gew. 1.19), die mit 25 cm³ H_2O verdünnt wurde, gegeben. Das Probiergläschen, das mit einem Glasdeckel nicht hermetisch geschlossen wurde, wurde in die Bombe eingebracht, die einem Luftdruck von 50 Atmosphären ausgesetzt wurde. Die Bombe befand sich in einem Ölthermostaten, der 22 Stunden lang auf 150° C gehalten wurde.

Hierauf liess man die Bombe abkühlen, schraubte sie auf, und der Inhalt des Probiergläschens wurde folgendermassen analysiert: erst wurde das Gewicht des nichtgelösten Pt bestimmt und dann das Gewicht des Pt, das sich aus der Lösung in Form von Ammoniumplatinchlorid oder Pratinmoor abgesetzt hatte.

Die Versuchsergebnisse bei verschiedenen Luftdrucken und sonst gleichen Bedingungen sind in der Tabelle (S. 557, oben) angeführt.

Bedingungen: Gewicht des Platinschwamms 0.5 g; HCl-Volumen 50 cm³; Temperatur 150° C; Versuchsdauer 22 Stunden.

Wie aus der Tabelle ersichtlich ist, wächst die Lösungsgeschwindigkeit proportional mit der Zunahme des Luftdrucks.

Es ist zu bemerken, dass die geringe Lösungsgeschwindigkeit dadurch zu erklären ist, dass es nicht umgerührt wurde, weswegen die Berührungs-

Luftdruck atm.	Prozentsatz d. gelösten Pt
10	1.3%
50	7.6%
85	12.0%
100	16.7%

oberfläche der drei Phasen: Metall—Lösung HCl —Luftsauerstoff sehr gering war. Die weiteren Versuche wurden daher in einem Autoklave mit Rührer durchgeführt.

Zur Illustration der Bedeutung des Umrührens seien die Ergebnisse zweier paralleler Versuche in einer einfachen Bombe und in einem Autoklave mit Rührer angeführt: bei sonst gleichen Bedingungen lösten sich im Autoklav mit Rührer innerhalb 6 Stunden 89% des benutzten Platins, während in der einfachen Bombe nach 16 Stunden sich nur 11.6% gelöst hatten.

b) Einfluss der HCl-Konzentration auf die Lösungsgeschwindigkeit von Platin

Die Versuche wurden im Autoklave mit Rührer von 500—600 Touren/min. Umrührungsgeschwindigkeit ausgeführt. Die Durchführung und die Analyse der Resultate war dieselbe wie bei den Versuchen in der einfachen Bombe.

Die Versuchsergebnisse haben, wie zu erwarten war, gezeigt, dass mit Erhöhung der HCl-Konzentration die Lösungsgeschwindigkeit des Platins in der Salzsäure zunimmt. So sind z. B. bei 100° C, 50 atm. Luftdruck und gleichem Volumen des Lösungsmittels und der gleichen Pt-Menge die nach Verlauf von 6 Stunden erhaltenen Resultate folgende:

Gelöstes Platin in Prozenten zur benutzten Menge	
in 1*n* HCl	34.0%
in 2*n* HCl	45.6%
in 6*n* HCl	60.4%
in 12*n* HCl	88.9%

Bei 100° C und 50 atm. Luftdruck gelang es, nach Ablauf von 48 Stunden Platinschwamm fast vollständig aufzulösen.

Gegen Schluss des Versuches ist eine Verzögerung des Prozesses zu verzeichnen, wenn geringe Mengen, offenbar die grössten Körner des Platinschwamms, zurückbleiben. Hiervon zeugen die Reaktionsgeschwindigkeitskonstanten, die aus der Gleichung der monomolekularen Reaktion unter der Annahme berechnet worden sind, dass die Konzentrationen von HCl und O_2 (50 atm. Luftdruck) während des Prozesses praktisch konstant bleiben.

c) Einfluss der Temperatur auf die Lösungsgeschwindigkeit von Pt in HCl

Nach 2 Stunden	$K = 0.0038$
» 6 »	$K = 0.0023$
» 12 »	$K = 0.0026$
» 24 »	$K = 0.0015$

Insofern das Gleichgewicht $2HCl + O \rightleftarrows H_2O + Cl_2$, das die Konzentration des Chlors bestimmt, das mit dem Platin bei dessen Auflösung in HCl bei Luftdruck reagiert, bei Temperaturerhöhung sich von links nach rechts verschieben muss, muss folglich auch mit der Temperaturerhöhung die Lösungsgeschwindigkeit des Platins beträchtlich zunehmen.

Die Versuchsergebnisse bestätigen diese Vermutung; nämlich bei 50 atm. Luftdruck und bei sonst gleichen Bedingungen lösten sich innerhalb 6 Stunden die hier unten in % angefürten Portionen der verwendeten Platinmenge.

bei 25°	10.5%
» 50°	17.7%
» 100°	60.4%
» 150°	89.0%

Bei 150°C und 50 atm. löst sich nach 12 Stunden Platinschwamm in 6*n* HCl vollständig.

Eine weitere Temperaturerhöhung muss den Lösungsprozess des Platins noch mehr beschleunigen, wenn nicht die Grenze erreicht wird, bei welcher der hydrothermische Zerfall der Platinchloride einsetzt, wie dies der Fall bei einigen anderen Edelmetallen ist.

II. Über die Auflösung anderer Edelmetalle in Salzsäure

Es ist von uns experimentell festgestellt worden, dass man Pt und Au nicht nur in Königswasser auflösen kann, sondern auch in HCl unter Beifügung eines Oxydationsmittels, insbesondere von H_2O_2. Folglich ist es ganz natürlich anzunehmen, dass bei hohem Luftdruck diese Metalle sich lösen werden, und die Frage nach der Geschwindigkeit dieses Prozesses wird zum Gegenstand weiterer Untersuchungen. Problematischer ist schon die Möglichkeit der Auflösung in Königswasser praktisch unlöslicher Metalle, wie beispielsweise Ir und Rh. Ein prinzipieller Unterschied zwischen dem Lösungsmechanismus dieser Metalle in Salzsäure in Gegenwart eines Oxydationsmittels und dem Lösungsmechanismus von Pt ist natürlich nicht vorhanden. Die ganze Frage besteht nur in der praktischen Erzielbarkeit einer genügenden Geschwindigkeit dieser Prozesse.

Bis jetzt haben wir nur einige Stichversuche auf der Suche nach passenden Bedingungen zur Erzielung einer praktisch messbaren Lösungsgeschwindigkeit von Ir, Rh und anderen in Königswasser nicht löslichen Metallen unter Druck in HCl gemacht. Diese orientierenden Versuche zeigen, dass eine systematische Untersuchung sowohl in theoretischer als auch in praktischer Hinsicht zu interessanten Resultaten führen kann. So z. B. gelang es uns nach einigen Stunden sogar ohne Umrühren in einer gewöhnlichen Bombe einen beträchtlichen Teil (ungefähr 30%) des zur Auflösung in HCl bestimmten Ir und Rh, welche sich absolut nicht in Königswasser lösten, zu lösen. Mittels Umrühren bei hohem Druck konnte man die Auflösung von Ir und Rh in HCl noch bedeutend beschleunigen. Die Schwierigkeit liegt darin, dass eine sauerstoffbeständige Apparatur verwendet werden muss, und dass ausserdem nach Erreichen einer gewissen Temperaturgrenze der umgekehrte hydrothermische Zerfall der komplexen Salze von Iridium und Rhodium, die sich schon in Lösung befinden, eintritt. Auf die Möglichkeit eines Gleichgewichts zwischen den zwei entgegengesetzten Prozessen—der Auflösung des Metalles und des hydrothermischen Zerfalls, der sich bei der Auflösung bildenden Salze—weisen die kürzlich durchgeführten Versuche von Ogryzlo([13]) über hydrothermische Prozesse mit Goldlösungen und unsere Versuche über die Hydrolyse von Ir- und Rh-Salzen bei Stickstoff- und Luftdruck hin. Die Untersuchung dieser Prozesse wird fortgesetzt.

Laboratorium für hohe Drucke.
Institut für allgemeine und anorganische Chemie.
Akademie der Wissenschaften der UdSSR.

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GENETICS

ON THE GENOTYPIC CONTROL OF STRUCTURAL CHROMOSOME CHANGES

By G. A. LEVITSKIJ, Corresponding Member of the Academy

Investigations of recent years have shown with great clarity the evolutionary significance of structural chromosome changes([1]). In a far less satisfactory state is the problem of the causes of these changes in the process of evolution. The potent source of artificially induced changes in chromosome structure, X-rays, is acknowledged to be a most insignificant factor as regards mutations under natural conditions([2]). The same also holds true for structural chromosome changes. The aging of seeds, advanced by M. Navashin([3]), cannot be recognized as a factor of general biological significance. The formation of structurally new chromosomes as a result of distant hybridization([4],[5]) assumes the existence of karyo-structural differences between the species crossed.

In a number of reported instances of the spontaneous origin of structural chromosome changes they were connected with the alteration of the karyological balance as a result of hybridization ([6],[7]) or of a trisomic ([8],[9],[10]) or monosomic ([11]) condition. In all these instances, however, the chromosome changes appeared in the progeny of karyologically unbalanced plants as peculiarities of definite individuals, i. e., in all their cells. Hence, they might have originated as a result of an unusual mode of crossing-over. As real proof that structural instability of chromosomes is genotypically controlled can serve only instances of variability within an individual as regards chromosome dislocations, especially if such variability occurs throughout a family or line of individuals.

The first such data which have been reported([12]) concern the progeny of trisomics (complete or partial), 3 out of 12 «abnormal» of which progeny (the total number being 71) proved to have cells in some of their root-tips with translocations. Fragmentation and other chromosome dislocations were observed by us ([13]) to be not a rare «intra-individual» phenomenon in some rye plants having special «supernumerary» chromosomes. Such cases were revealed in 28 out of 52 investigated plants. Moreover, in the progeny of individuals not exhibiting such phenomena the number of the «intra-varying» plants amounted to almost $\frac{1}{2}$ (20:22), and in the progeny of «intra-varying» individuals to $\frac{4}{5}$ (8:2). This indicates hereditary transmission and, consequently, genotypic control of «structural instability» of chromosomes. The common occurrence of fragments was observed by A. Fetisov (unpublished data) also at miosis (diakinesis, first metaphase) in the same «16-chromosome» rye.

Particularly significant likewise is the frequency of structural chromosome changes in inbred rye([14]); their presence in a heterozygous condition,

despite inbreeding, may be explained most naturally by their constant induction as a result of definite homozygous genotypic combinations*.

To phenomena of the same category belong, apparently, the characteristic «irregularities» at mitosis observed in distant hybrids and in some individuals of their progeny([15]), as well as the occurrence of supernumerary «dwarf chromosomes» in their first generation([16]). Despite the paucity of the cited data, it nevertheless leads one to conclude that the genotype exerts an influence on the structural variability of chromosomes([17]).

A definite solution of the problem as to the genotypic control of structural chromosome changes may be obtained only by investigations especially conducted for this purpose, utilizing a large number of plants for experiment and as controls. These requirements have been fulfilled, to a certain degree, by the data we have obtained from plants belonging to the direct progeny of X-rayed *Crepis capillaris* plants (F_1, according to our designation). These data have reference to structurally changed chromosomes found side by side with normal chromosomes in one and the same individual. Such intra-individual changes in the F_1 of our material attracted our attention from the very beginning of the investigation, and induced us to make a more precise and comparative analysis of them.

As data of the nature of a control we may take the results obtained by M. Navashin on «Variabilität des Zellkerns bei Crepis-Arten in Bezug auf die Artbildung»([18]), since the seeds for our present investigation, kindly provided us by M. Navashin, originated from the material he used in this investigation. He subjected 3280 *Crepis capillaris* plants to cytological analysis**, and for this species he does not report any instances of «variability» in chromosome morphology. Apparently, under natural conditions chromosome morphology in *Crepis capillaris* is very stable. On the other hand, in the progeny of X-rayed plants, as we shall see, such changes constitute a quite conspicuous phenomenon.

In our final analysis of the data pertinent to this investigation we subjected these data to a most severe test, and any regarding which we were the least bit doubtful or uncertain were excluded. Nevertheless, after such exclusion, we found among 295 plants, by examining 2109 plates, 25 cases of indubitable deviations in chromosome morphology***. Nine of these were typical translocations of large segments; two were translocations of satellites; five were changes in the size of corresponding parts of homologous chromosomes, clearly perceptible, but not of such a nature as to make it possible to determine definitely the precise character of the dislocation; five were secondary constrictions; and four were fragmentations. All these intra-individual chromosome changes were not distributed at random and evenly throughout all the investigated material, but were concentrated in definite families and wi-

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* The hypothesis of selection of especially heterozygous inversions advanced by the author (p. 236) as an alternative postulate, seems extremely difficult to motivate.

** «Insgesamt wurden auf diese Weise 3280 Exemplare von *Crepis capillaris* (9840 Wurzelspitzen) und 4010 Sämlinge von *Crepis tectorum* (1230 Wurzelspitzen) fixiert; die gesamte Individuenzahl, welche untersucht wurde, überstieg somit die Zahl sieben Tausend» (p. 178). However in the Summary (p. 213) the author, for some unknown reason, gives the number of investigated individuals of *Crepis capillaris* as «gegen 2000». After a letter of the author the number 3280 represents the plants of *Crep. cap.* which were fixed, and 2000, the plants actually investigated.

*** A deviation repeated in a single root-tip or sector of a root-tip was counted as one.

A. Families with deviations				B. Families without deviations		
Family No	Number of deviations	Number of individuals investigated	Number of plates investigated	Family No	Number of individuals investigated	Number of plates investigated
2467	6	8	45	2532	39	135
2501	5	19	90	2470	20	93
2536	3	10	36	2472	15	61
2464	2	8	33	2469	11	51
2466	2	16	71	2473	12	48
2468	2	13	66	2503	9	35
2465	1	17	89	2475	10	29
2471	1	23	75	2461	6	29
2474	1	14	53	2502	4	24
2491	1	7	33	2515	7	23
2533	1	14	40	2534	5	16
				2517	7	15
				2535	6	14
				2516	2	9
				2500	1	4
				2516	1	2
				2519	1	2

thin such families in definite individuals. It is clearly shown in the Table, which summarizes the results of the investigation.

About half of all the deviations (11 out of 25) were found in two families (25 investigated) — 2467 and 2501. In the first of these, Family 2467 (8 individuals, 45 plates investigated), there were found 6 deviations: 3 translocations in one individual with an «inversion» in the *D*-chromosome; 2 fragmentations (*D*- and *A*-chromosomes) in one individual;and 1 translocation in individual with an extra appendage on *D*. In the second, Family 2501 (19 individuals, 90 plates investigated), 5 changes were noted: the first, a translocation («from *A* to *C*»), and the second, the loss of the *C*-chromosome with the translocation of part of it to *A*—both changes in one individual; the third, a translocation («from *C* to *A*») occurring in the same individual as the fourth, a distinct constriction (or fragmentation) on the short arm of *A*; the fifth, a translocation («from *D* to *A*») occurring in another individual.

In Family 2536 (10 individuals, 38 plates investigated) all three deviations* are concentrated in one plate; in Family 2468 (13 individuals, 66 plates) two deviations in the same chromosome *D***; in Family 2464 (8 individuals, 33 plates) two deviations in one plate***; in Family 2466 (16 individuals, 71 plates) also two deviations in one plate****. Hence, only five (out of 25) deviations occurred singly in different individuals*****.

The six families which showed more than one deviation were not subjected to more detailed investigation (i. e., a larger number of individuals and plates were not investigated) than were the same number of families

* 1) Inequality in size of heads of the *C*-chromosomes; 2) increase in size of satellite; 3) secondary constriction on the long arm of *A*.

** 1) Increase in size of head; 2) fragmentation.

*** 1) Translocation of satellite «from *D* to *C*»; 2) fragmentation.

**** 1) Inequality in length of long arm of *C* (translocation?); 2) fragmentation of short arm of *A*.

***** 1) 2465 — inequality in length of short arm of *A*; 2) 2471 — appearance of a head on long arm of *A*; 3) 2474 — translocation «from *C* to *A*»; 4) 2491 — appearance of satellite on the head of *C*; 5) 2533 — marked increase in length and distinct constriction of short arm of *C*.

not showing deviations, if we take the six of the latter families investigated to the greatest extent. This is clear from the table (A and B), which gives the number of individuals and plates investigated in each family. The total number of investigated individuals in the six families with more than one deviation was 74, and in the first six families without deviations—106; the number of plates investigated—343 and 423, respectively.

From all the forgoing it follows that those families which gave a larger number of deviations are inclined to give such deviations, this inclination being especially marked in some particular individuals in these families. This «inclination» can scarcely be interpreted in any other way than genetically, i.e., as due to definite peculiarities of the genotype. Since these peculiarities appeared only in the progeny of certain of the plants subjected to X-radiation, they are apparently the result of X-ray-induced mutations, which brought about genotypically determined instability of the chromosomes and which were transmitted through the female gametes to the F_1.

The genotypic control of structural chromosome changes accounts in a natural way for the marked differences as regards such changes in different sections of the taxonomic system. The exceptional frequency of structural chromosome changes in the evolution of species of *Oenothera* and *Datura*[19] stands in contradistinction, for example, to their almost complete absence in the divergence of the genera *Festuca* and *Lolium*, as far as this may be judged by the complete and normal conjugation of chromosomes in hybrids between these genera[16]; the fundamental reconstruction of the chromosomes of *Drosophila miranda*, as compared with those of the closely related *D. pseudoobscura*[1], stands in contradistinction to the comparatively insignificant differences in this respect between *D. melanogaster* and *D. simulans*[20].

On the other hand, the genotypic control represents a factor which may explain in a natural way the general occurrence of structural changes of chromosomes in both animal and vegetable kingdom*.

Genotypic control of structural chromosome changes does not exclude, of course, the influence of divers other factors, both external and internal, working in the same direction. This influence, on the contrary, can only be facilitated and reinforced by favorable genotypic conditions.

Cytological Laboratory
Institute of Plant Industry.
Leningrad—Pushkin.

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* That gene mutations of a «spontaneous» nature may be similarly accounted for, has begun to be established in very recent years ([21–22]).

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PLANT PHYSIOLOGY

THE ACTIVATORS OF PEROXIDASE IN SICK PLANTS

By K. SUCHORUKOV and B. STROGONOV

(Communicated by A. A. Richter, Member of the Academy, 21.IV.1937)

The condition of the oxidation-reduction system in case of sickness of the plant has come in for a great deal of attention; the changes of the indices of the various components of the system make it possible, in some cases, to make a rapid diagnosis of the extent of the stability of the plant([4]), its dynamics due to the action of external agents([5]), and the extent of the resistance of the plant to sickness([6]).

Most sicknesses due to facultative parasites begin with an increase of oxidation reactions at the points of infection, the outward expression of which is the necrosis of some portions of the tissue, and darkening. In the case of hadromicosis, the darkening of the live elements of the vascular system is so marked as to serve as a reliable guide to the occurrence of mycelium in the tracheae of the organs.

The mechanism of the increase of oxidation reactions due to an infectious disease of the plant has not yet so far been fully accounted for, nor has it been possible fully to ascertain the influence of these reactions on the resistance of the tissues to the invading parasite.

A sharp rise in the activation of peroxidase has been discovered by the writers in the roots and in the petioles of the cotton plant when its vascular system has been attacked by the parasitic fungus *Verticillium albo-atrum* R. et B. Thus, the roots of a sound plant gave 5.0, those of a sick one 11.4, the petioles of a sound plant yielded 5.1, those of a sick one 10.0 (the indices are in c^3 of a $n/10$ potassium permanganate per 1 g of raw mass; pyrogallol method).

As shown by Oknina's investigations, the two species of *Verticillium* parasitizing on the cotton plant (*V. albo-atrum* and *V. dahliae* Klebahn) possess the property of discharging into the medium a large amount of hydrolytic ferments, which ensure the supply to the parasite of organic substances easy to assimilate. Our supposition was that, along with the hydrolytic ferments, the fungus discharged peroxidase into the juice of the tracheae, thus activating the oxidizing processes taking place in the live cells of the plant. To verify this supposition, we studied the activity of peroxidase in both *V. albo-atrum* and *V. dahliae* grown on a saccharomineral medium. The determination of peroxidase was made by the pyrogallol method, both in the mycelium and in the medium, at different ages of the fungus. The data obtained by the analyses are given in Table 1.

Table 1

Name of fungus	Age of fungus in days	Peroxidase in the mycelium	Peroxidase in the medium
V. dahliae	30	0.0	0.0
» »	38	9.4	Traces*
» »	58	0.0	Traces*
V. albo-atrum	30	8.5	0.0
» »	38	3.0	0.0
» »	58	7.0	Traces*

Note. The activity is expressed in cm^3 of $n/10$ potassium permanganate per gram of the raw weight of the mycelium and an amount of cm^3 of the medium corresponding to 1 g of mycelium.

The activity of the peroxidase in the mycelium being comparatively low, the diffusion of the ferment into the medium is negligible; there is no reason to expect that the activity of the peroxidase of the organs affected should be increased owing to the supply of the ferment produced by the parasite; verticellosis can scarcely be expected to produce a mechanical irritation of the live cells, since no penetration of the hyphae of the fungus into the living protoplasm can take place unless the cells have lost most of their turgour(2).

Hence, the cause of the changes in the chemism of the cells of the host plant must lie in the humoral action of the parasite on the oxidizing system of the cell. The presence in the cells of certain substances activating the oxidation processes has been established by Batelli and Stern(1), who obtained, from comminuted muscles, extracts containing an active principle termed «pnein». Further investigations have shown the live cell to produce a number of substances catalyzing the oxidation reactions both in vivo and in vitro(3).

The writers investigated the changes in the activity of peroxidase in the presence of the discharges of the fungus into the medium and of extracts from the mycelium itself. The preparation of peroxidase used was a freshly-prepared aqueous extract of horse-radish (1:10), known to possess a high peroxidase activity. The effect of the activator was determined from the difference in the titration of purpurogalline with a $n/10$ solution of $KMnO_4$ following upon the action of peroxidase plus activator, and that of peroxidase alone. The preparation of the activator used was the medium after a culture of *Verticillium* thereupon, and an aqueous extract from fresh mycelium (1:5). Cultures of various ages were investigated. The addition of the activator preparation was the same in all the experiments, viz. 5 cm^3 for the total volume of the reacting mixture prepared after the method adopted by the writers(7), in this manner we measured the concentration of the active principle in the liquids under investigation. The obtained values of the changes in the activity of peroxidase in cm^3 of an $n/10$ solution of potassium permanganate are given in Table 2.

The above figures show that, side by side with small amounts of peroxidase (cf. Table 1), the fungus discharges into the medium a large amount of the activator which increases the activity of the peroxidase derived from another source (horse-radish). In a medium of old cultures (58 days), the accumulation of the activator was the greatest.

* Reaction with guaiacum resin.

Table 2

Name of fungus	Age of fungus in days	Activators	
		Mycelium extract	Medium
V. dahliae	30	1.1	1.7
V. albo-atrum	30	—3.5	5.5
V. dahliae	38	—3.3	1.3
V. albo-atrum	38	—0.3	0.5
V. dahliae	58	1.3	9.0
V. albo-atrum	58	—0.7	8.7

Mycelium, while producing the activators, does not seem to retain them in its cells. A certain, and sometimes considerable inhibition of the reaction (minus activation) would seem to indicate the presence, in the mycelium itself, of certain substances of the type of fermentation inhibitors; it is this latter fact that sometimes appears to prevent the discovery of an active peroxidase in the fungus itself([8]).

The discovery of peroxidase activators discharged by *Verticillium* into the nutritive medium reveals the chemism of the processes accompanying the progress of the fungus along the vascular system of the plant. In their histochemical investigations of the stem, the writers discovered a high activity of the peroxidase in the parenchymatic cells adjoining the vessels; the diffusion of substances from the affected tracheae introduces the activators into the adjoining live cells, thus disturbing the equlibrium of the fermentative system. The intensification of the oxidizing processes in the cell results in its necrosis and thus destroys the resistance of the live cells to the developing parasite. Owing to some peculiarities of its chemism, *Verticillium* retains, even in a living plant, the properties of a saprophitic microbe eliminating all living cells from the sphere of its influence.

Institute of Plant Physiology.
Academy of Sciences of the USSR.

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PHYTHOPATHOLOGY

ON THE SO-CALLED MASKING OF VIRUS DISEASES

By M. I. GOLDIN

(Communicated by G. A. Nadson, Member of the Academy, 26. IV. 1937)

The phenomenon of the so-called masking of mosaic diseases, which is of such great practical significance and theoretical interest, has hardly been at all studied.

«Masking, as Prof. Ryžkov notes(1), makes a true estimation of the extent to which cultures are affected very difficult and thus hinders the selection of healthy specimens».

According to Proida's data(2), 50 per cent of the beet infected with the mosaic disease (the examination was made on June 4, 1929) were found to be masked by August 8, i. e., they bore no external symptoms of the disease. In another case, on a plantation with an 80% infection, the remaining 20 per cent of roots were planted next year and showed a 100 per cent infection. On the basis of these observations, the writer concludes: «the selection of healthy roots for planting, with the object of freeing the beet from the mosaic disease, is futile when the whole field is highly infected».

According to Priece(3), tobacco which has suffered from ring-spot and has lost all external symptoms of the disease does not respond to new infections. The virus, however, not only is preserved in the recovered plant, but multiplies in it.

Borisevič(4) believes that the disappearance of external symptoms of the disease depends on the stage of growth of the plants and, in some cases, on meteorological conditions. Proida regards masking as the transition of the disease into a latent state; which may be due, either to late infection «or to not all plants displaying the symptoms of their infection at the same vegetative period».

After Johnson(5), the symptoms of the mosaic disease in plants infected with the tobacco mosaic virus become completely or partly masked at temperatures of 35—37°. He explains this by the great fall in the concentration of the virus.

Tobacco infected at temperatures below 15° and above 37° remains healthy. In any case, even if the plant is infected, the disease is masked, as far as external symptoms are concerned. It should be noted that the term «masking» does not describe the real state of affairs. We can speak, for instance, of the masking of chlorophyll in anthocyanine plants. But the absence of a mosaic pattern in plants infected with the virus is not masking. This phenomenon may be due to a number of different causes.

During the vegetative period of 1936, we had under observation more

than a thousand tomato plants infected with the tobacco mosaic virus. The experiments were carried on in a hot-house. 300 of the tomato plants were infected at the end of spring. In these plants, the mosaic pattern persisted for up two months. In some specimens, it disappeared in about a month. With the onset of hot weather, when the temperature in our hot-house rose sometimes up to 38°, the majority of the plants lost their mottled appearance. But, even at that temperature, some specimens retained a distinct mosaic pattern.

On inoculating the leaves of *Nicotiana glutinosa* with the juice from tomato plants which had lost their mosaic pattern, we always obtained a large quantity of necroses.

A little later (in 10—20 and more days), the mosaic pattern reappeared on the leaves of outwardly healthy tomato plants. Then this mottled pattern disappeared again, and so on. In the different batches of the tomato the masking did not appear simultaneously. In 30 plants, distinct mosaic pattern could be observed on young leaves as late as the end of December.

According to our observations, the disappearance of the mosaic symptom was associated, not only with temperature conditions, but in many cases, with the duration of the disease.

Masking mostly occured in those plants that had heen inoculated at early dates, independent of the age of the plant. This may be a phenomenon analogous to non-sterile immunity.

On the basis of the above observations, it seemed interesting to elucidate the incidence of masking on tobacco plantations.

I have already noted above, that the masking of the mosaic disease in the beet is of practical significance. There are no data, however, on the incidence of masking of the mosaic disease on tobacco plantations.

In accordance with Prof. Ryžkov's suggestion, we carried out an examination of the tobacco plantations of the «Ilyich» collective farm in Alushta. The examination was made at the end of August and the beginning of September.

The tobacco plantation of this collective farm consists of widely scattered, small plots (of 1—2 hectares). The percentage of infected plants (determined after external symptoms) was very different on the different plots.

Thus, our observations showed that the tobacco plants on the plots near an old cemetery and tobacco shed were 100 per cent infected. On the plots in the collective farm orchard, the percentage of infected plants was 18—28%, while on the plots situated on a small eminence it was 28—40%.

The percentage of masking was estimated on 5 plots.

Plot No 1. 36% infected with the mosaic disease. This plot lies on an eminence, among vineyards.

Plot No 2. 28% infected with the mosaic disease. Lies at a somewhat greater altitude (about 440—500 m above sea level), also among vineyards.

Plot No 3. 28% infected with the mosaic disease. Located in the collective farm orchard and surrounded by fruit trees.

Plot No 4. 18% infected with the mosaic disease. Likewise situated in the collective farm orchard, among vegetable cultures.

Plot No 5 consisting of small garden growths uninfected with the mosaic virus, served as control.

The investigations were carried out as follows. After the percentage of infected plants had been determined, the upper leaves of plants showing no mosaic pattern were picked off by a sterile pincette and placed in separate envelopes. Inoculation with the juice pressed from these leaves in a sterile

mortar was made on the very day of sampling. Three leaves of *N. glutinosa* were inoculated with each sample. Control inoculations were made each time with the juice of the leaves of the tobacco plants from plot No 5.

The results are summed up in the following table:

Plot No	Percentage of manifestly diseased plants	Percentage of diseased plants among the outwardly healthy plants	Total percentage of diseased plants	Number of samples (total)	Number of samples that caused infection
1	36	87	91	30	26
2	28	60	65	25	15
3	28	43	59	28	12
4	18	20	35	20	4
5	0	0	0	10	0

As the above table shows, the percentage of masking on the tobacco plots was very high. The results obtained prove beyond doubt that determinations of the percentage of tobacco plants infected with the mosaic virus, made on the basis of external symptoms only, yield minimized figures. It is obvious that the markedly different percentage of masked plants within one collective farm cannot be accounted for by climatic factors or by the stage of growth of the plants, as the tobacco plants on all the plots were approximately of one age. It is likewise improbable that the mosaic disease of the masked plants had not yet had time to manifest itself, as we continued our observations of all the five plots for 25 days, during which time the masked plants did not develop any external symptoms.

It may be assumed that the masking of the mosaic virus is due, to a considerable extent, to a peculiar immunity of this plant. It will now be necessary to elucidate the development and distribution of the masking for the whole vegetative period. From the practical standpoint, it is important to determine the technical value of masked tobacco plants as compared with that of healthy and manifestly diseased ones.

Conclusions

1. Masking of the mosaic virus may be of very common occurrence on tobacco plantations.

2. Determinations of the incidence of the mosaic virus of tobacco based on external symptoms give minimized results.

3. The masking of the mosaic virus of tobacco appears to be due to a peculiar immunity of the plant.

Microbiological Institute.
Academy of Sciences of the USSR.

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ZOOLOGY

TWO NEW SPECIES OF *ARTEDIELLUS* JORDAN FROM THE OKHOTSK SEA

By P. J. SCHMIDT

(Communicated by S. A. Zernov, Member of the Academy, 7. IV. 1937)

Among the fishes collected in 1932 in the Okhotsk Sea by S. Somova-Generosova on the trawler «Gagara», one of the steamers of the expedition organized by the Pacific Scientific Fisheries Institute (Vladivostok) and the State Hydrological Institute (Leningrad), there occured two new and very interesting semibathybial sculpins, pertaining to the genus *Artediellus* Jordan. One of them, named by me *Artediellus nigripinnis*, differs but little from the general type of the species *Artediellus*; but the other (owing to its long, horn-like, preopercular spines named *Artediellus antilope*) displayed such great differences, that the question even arose whether it should not be considered as representative of a new genus. This at first seemed particularly probable, as A. J. Taranez found that its subocular bone is of a broad, flattened shape, whereas in *Artediellus* it seemed to be generally stick-shaped. However, a closer investigation showed that the shape of the subocular bone is variable and connected with the development of the preopercular spines: it is narrow and nearly stick-shaped in *A. pacificus ochotensis* Schm. with comparatively small preopercular spines and is broad and flat in *A. dydymovi* Sold. which has more developed and larger horns. I prefer therefore to regard both species as true *Artediellus* but somewhat specialized in connection with their semibathybial life. I give here only a short preliminary description of these species: the measurements and the figures will be published at a later date in my paper on the fishes of the Okhotsk Sea now in preparation.

1. ARTEDIELLUS NIGRIPINNIS sp. n.

D VII—VIII,12—13; *A* 9—11; *P* 21—23; *V* I. 3; *L. ltr.* 23—29; *R. br.* 6

Body elongate, compressed on the sides, flattened anteriorly, head large, 3 in body length; long diameter of eye 3 in head; mouth large; teeth in jaws, on vomer and palatines. No supraocular spines; occipital spines present, depressed. Head without flaps or tentacles.

Preopercle with 4 spines: the upper curved, $^2/_3$ diameter of eye; the second about $^1/_3$ the length of the first; the lower two being short. Many pores on head, large pores below the eye and on the lower jaw; on the last the median pores not confluent. Skin smooth, without warts or spines. Dorsal fins separate, second fin higher. Pectoral fin reaching behind anterior end of the anal fin, rounded. Caudal fin truncate. Small anal papilla present

in males. Colour yellowish-grey, darker on the head. Dorsal and anal fins black; caudal, ventral and pectoral fins blackish. Gill-membranes and mouth cavity blackish. Length 108—137 mm.

Found in the depth of 500—592 m of the central part of the Okhotsk Sea between Jona's Island and the western coast of Kamchatka (51°09′ N. lat. 154°17′ E. long. and 55°40′ N. lat. 143°04′ E. long.).

2. ARTEDIELLUS ANTILOPE sp. n.

D VII—VIII, 11—13; *A* 8—10; *P* 21—23; V I. 3; *L. ltr.* 20—23; *R. br.* 6

Body elongate, compressed, flattened anteriorly. Head 3 in body length; long diameter of eye 4 in head; interorbital space narrow; nasal spine small, shorter than nasal tubes; teeth in jaws, vomer and palatines. Preopercle with 4 spines; the upper long, antilope horn-like, 1.3—1.4 times the long diameter of eye, slightly curved, directed back and upward; the second spine about $^1/_3$ the length of the first, directed backward, the third spine smaller also directed backward, the fourth spine directed downward and forward; a sharp and well developed spine on the opercle. Many pores on head; a row of large pores below the eye and another on the lower jaw; on the last the two median pores confluent. A pair of small tentacles above the eyes. Bony tubercles with radiating striae and with blunt spines on the occiput. Occiput nearly flat. Body covered with smooth skin. 20—30 pores of the lateral line below the channel. A small cylindrical anal papilla in males present. Dorsal fins separated, the second higher, than the first. Pectoral fin reaching to the first ray of the anal. Anal fin shorter than the second dorsal. Ventrals not reaching anus. Caudal fin truncate. Colour greyish, head slightly darker; dorsal fins grey with a broad blackish border. Mouth and gill-cavities unpigmented. Length 75.8—107 mm.

Found only on the trawler «Gagara» station No 252 (55°31′ N. lat. 149°10′ E. long.), depth 335 m, ooze.

This species, however, differs from all the other species of *Artediellus* by its long horn-like preopercular spines, but the slight curvation of the last shows that they are connected with the curved spines of the whole *Artediellus*-group.

It seems to me more probable to assume that the curved spines originate from the straight ones and that *Artediellus antilope* represent a more primitive form of the *Artediellus*-group preserved in the depths of the Okhotsk Sea.

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EXPERIMENTAL ZOOLOGY

ON THE REGENERATION OF THE MYOID ELEMENTS OF THE THYMUS GLAND OF AMPHIBIANS

By A. M. VASJUTOČKIN

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For a number of years the thymus gland has been regarded as one of the most interesting objects of study owing to the occurrence of unexpected structural elements confusing our understanding of the structure of this organ. Such are first of all the so-called myoid elements, whose muscular nature has been established by me in a series of papers (1913, 1914, 1915).

The thymus gland of amphibians, which shows marked seasonal changes, is of especial interest to us, owing to the changes in its myoid elements that are associated with the changes in the general structure of the organ.

The thymus gland is usually an oval body, distinctly differentiated in summer into dark (cortical) and light (medullary) layers. Even under weak magnification, one observes the presence of a great number (sometimes from 40 to 50 in one field of vision of the microscope) of rounded elements noticeable owing to their great size as compared with that of the lymphocytes of this gland.

Notwithstanding the differences in their opinions on the origin of these formations, Pensa (1902—1905), Hammar (1905—1909), Weissenberg (1907), Dustin (1908—1920), and Pappenheimer (1910) are unanimous in finding that the structure of the myoid elements closely resembles that of stricted muscle-fibres. Let us, therefore, take the structure of a typical muscle-fibre as a criterion and ascertain to what extent the myoid elements occurring in the thymus gland of a frog deviate from this type.

It should be noted that the typical ribbon-shaped myoid elements, figured by Hammar and the present writer for birds, and by Dustin for reptiles, are almost entirely absent from the thymus gland of amphibians. Sometimes there occur club-shaped myoid elements, in whose enlarged nuclear part we do not distinguish any definite structure, while in its process we discern a distinct differentiation into dark and light discs with the presence of *Z*-bands.

The bulk of the myoid elements of the frog's thymus gland is, however, represented by the so-called concentric myoid elements. Although these formations are far removed from typical muscle-fibres, nevertheless, their similarity to the latter may be established down to the minutest details of

their structure. Their longitudinal (concentrical in this case) and transverse striations are indisputable. The presence of *Z*-bands may be noticed even in elements which are known to be in a state of disintegration.

The origin of these concentric elements is of great interest. Hammar and Dustin have established that the cell assumes its rounded form only during degeneration, while the study of the so-called transitional forms has shown the concentricity to be the result of a peculiar curling of the myoid elements. It should be noted here that the phenomenon of curling may also be observed in the disintegrating muscle-fibres of tadpoles during the metamorphosis.

Further changes in the myoid elements may proceed in different directions. Vacuoles with transparent contents appear sometimes in these cells, near the nucleus. Similar vacuoles appear also in other parts of the cell body and gradually merge into one large vacuole occupying the whole central part of the cell and displacing the differentiated protoplasm to the periphery. Ver Eecke's (1899) «secretory vesicles» result.

As regards the changes in the myofibrillae of the myoid elements, it may be first of all established that the alternating dark and light discs undergo displacements, and a subsequent weakening of the affinity of the *Q*-elements for dyestuffs and then their dissolution in the protoplasm occur.

Finally, the time comes when we cannot distinguish any structure in the protoplasm. Such myoid elements are usually markedly vacuolized and subsequently disappear through autolysis; the intrusion of elements undergoing phagosytosis rarely occurs.

The nucleus of typical myoid elements is light and vesicular, contains one or two nucleoli and is poor in chromatin. During degeneration, it wrinkles up, stains much stronger, the chromatin condenses into one or two lumps and finally the nucleus undergoes complete pyknosis.

As regards the multiplication of the myoid elements, I have not observed any figures of karyokinetic cell-division. Even the occurrence of direct cell cleavage is far from frequent. Hence the question naturally arises as to the cause of the increase in numbers of the myoid elements in summer.

In spring, giant cells appear in the thymus gland which are distinguished not so much by their size as by the considerable number of nuclei they contain, the latter being sometimes closely packed into one compact group and sometimes, on the contrary, arranged as a ring along the periphery.

The nature of these formations was for a long time obscure to me, and only after examining a giant cell by means of serial sections I succeeded in establishing that it terminates in a concentric myoid elements, of a structure typical for these formations. Thus, a certain part of the giant cells of the thymus gland belongs to the group of its myoid elements.

What is the nature of these formations? It has been established that the myoid elements are dying formations but are not yet dead. If this is so, they justify the principle that, concurrently with processes of physiological degeneration, the inverse process of regeneration occurs.

We know from Schminke's investigations (1908, 1909) that the formation of muscle-fibres from myoblasts during regeneration occurs but very rarely. Regeneration is mainly due to the formation of muscle-buds at the ends of already existing muscle-fibres. The end of an injured muscle-fibre produces a sarcoplasmic bud; the nuclei at this point start dividing amitotically and produce a peculiar chain of nuclei. As for the contractile substance, the striated fibrillae are converted into smooth ones, and the latter disappear in the sarcoplasm of the muscle-bud.

It is interesting that the cross-section of such a muscle-bud, especially when the nuclei in it are displaced, shows a typical picture of a giant cell of the thymus gland.

If we take into account the fact that cross-sections may pass through different places of the muscle-bud, it becomes clear that we may encounter, first of all, cells with an entirely homogeneous sarcoplasm, i. e. «cellules épithélioïdes» of Dustin. «All the myoid cells,—says this author,—pass through this stage; these are—young cells». If the cross-section passes at the place where we have smooth fibrillae, we obtain a transitional type of cells, «cellules leiomyoïdes». Lastly, a section through that part where the fibrillae show a differentiation into dark and light discs, will remind us of the «cellules rhabdomyoïdes».

Thus we have established that while the myoid elements degenerate, a part of them winters in the adult organism, and that in spring, when the supply of nutrient salts in the organs increases, the thymus gland is again filled with myoid elements.

A series of facts described by Dustin support our suggestion. Thus, he states that cells with 4—5 nuclei are rare in the thymus glands of June frogs, but that at the beginning of spring it is possible to find cells with an immeasurably greater number of nuclei. Further, «cellules épithélioïdes» predominate in the thymus gland in spring, while «cellules leiomyoïdes» predominate in June. Typical myoid elements are of very rare occurrence in tortoises in spring, while their number markedly increases in summer. The facts that were unintelligible to that author are now easily accounted for: it is a picture of the gradual differentiation of the muscle-buds formed during the regeneration of the myoid elements.

I have shown in a series of papers that in their minutest structure these formations resemble, in their most typical cases, striated muscle-fibres. The study of their degeneration has shown this process to be similar to the changes occurring in the degenerating muscle tissue. I hope that the data cited in this paper will suffice to show that the regeneration of the myoid elements occurs after the manner of the formation of muscle-buds, and thus will supply a new proof of the muscular nature of the myoid elements of the thymus gland.

Histological Laboratory.
3rd Leningrad Medical Institute.

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